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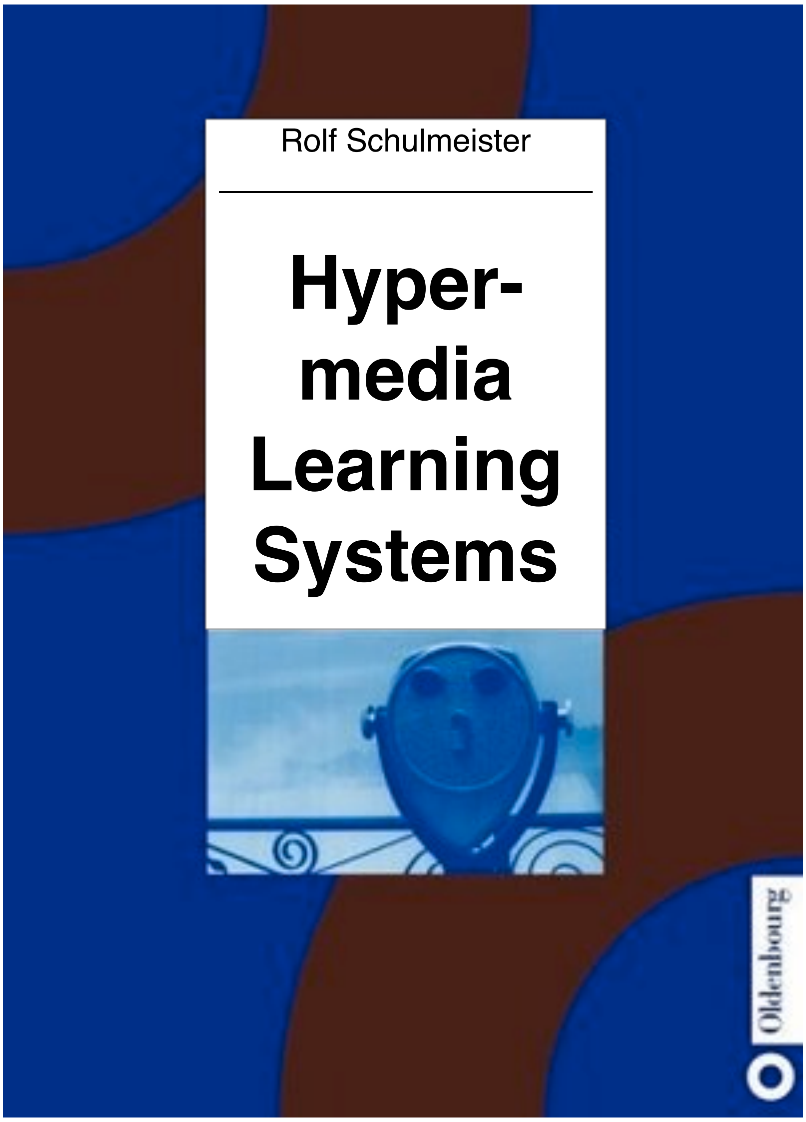

Hypermedia Learning Systems

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Contents

Chapter 1

Introduction

Hyperlearning – An Extreme Position

One might of course justify the use of multimedia in schools like this: »Many a student has been frustrated by a professor who simply did not know how to teach« [Jones (1992), 2]. Should it be the aim of multimedia to replace the teacher? Should multimedia represent the perfect teacher, offer the perfect educational strategy? Can multimedia do that at all? Or would such demands put an overload on multimedia?

Elshout (1992) seems to have a similar direction in mind when he criticizes traditional school education as follows: »It seems that formal education lets you get away with a great amount of half digested knowledge« (15). Should one of the tasks of multimedia then consist of making a contribution to avoiding half digested knowledge?

One can of course criticize much about education in school and in higher education. One might also link this criticism to the conclusion that teachers and professors should get better pedagogic training, and that their teaching ability should be tested more thoroughly before anyone is appointed teacher or professor. But criticism of the status quo is no sufficient reason, at any rate, for the introduction of multimedia as a new form of teaching or new method of learning. On the contrary, if one looks at some of the multimedia programs on offer today, one might be inclined to agree with Winn (1989), who comments with regard to learning programs that imitate teachers: »good teachers are presently better than machines at making decisions and at instructing« (44).

Hyperlearning

One could also argue as Perelman (1992) does in his book with the programmatic title »School's Out«, who wants to shut down schools with the introduction of so-called »Hyperlearning«, because they are too costly institutions (106). Perelman sees the institution school from an economical perspective, as a labour-intensive branch of industry with low productivity (98). From the point of view of modern communication and information technologies, school seems to him an archaic form of production with rising labour costs, while modern communication technology becomes more and more effective. For Perelman, it is not scientific or educational reflection that determines the existence of school, but simply the dramatic drop in costs for technological products in the interplay of forces of the free market: »The time has come to insist on the real free enterprise restructuring of the education sector that will deliver lots more bang for lots fewer bucks« (114).

Perelman is reacting to the importance multimedia has in his opinion: »The establishment of multimedia will have as profound an impact on all future communications as the invention of writing had on human language« (39). Whether this assessment of multimedia as a second Gutenbergian revolution is a realistic one will become apparent in the course of this book. My more conservative prognosis will at all events not come to the conclusion that Perelman arrives at: »In the wake of the HL revolution, the technology called 'school' and the social institution commonly thought of as 'education' will be as obsolete and ultimately extinct as the dinosaurs« (50).

Perelman coins the powerful term »hyperlearning« for the combination of multimedia or hypermedia and learning: »It is not a single device or process, but a universe of new technologies that both process and enhance intelligence. The hyper in hyperlearning refers not merely to the extraordinary speed and scope of new information technology, but to an unprecedented degree of connectedness of knowledge, experience, media, and brains – both human and nonhuman« (23). Perelman is fascinated by the attractiveness of new media for young people. He repeatedly cites examples as evidence that take up a certain amount of room in the media's current reporting. But such experiments have not been around for very long, and such experiences are therefore not suited to support his theses. What will happen once the new technological options are a matter of everyday routine, and a generation has already grown up with them? Will students not accept them as a matter of course, just like they do reading books or watching television today?

Hyperlearning is a revolution to Perelman. Not modest in the least, he extends the importance of hyperlearning to the social and political sector: »The hyperlearning revolution demands a political reformation. And that requires completely new thinking about the nature of learning in a radically changed future that now sits on our doorstep« (24). He does see the danger of information overload and recognizes, at least in this respect, the difference between information and learning, but for Perelman the key to dealing with the information overload lies in the potential of artificial intelligence, of which he has great hopes.

Is he right? Will artificial intelligence experience this fast rise? Or will research discover principal limitations of AI? Why does Perelman not discuss the arguments of other well-known supporters of the hypermedia sector, e.g. Landauer (1991), who formulates an alternative thesis: »the theory of human cognition is now and may forever be too weak to be seen as the main engine driving HCI« (61). Why does Perelman suppose that the huge network of hyperlearning – if it comes to pass, that is (as of now, this is prevented by proprietary rights of copyright holders, which make multimedia more expensive than the school education which Perelman brands as too costly) – will automatically cause all human beings to learn? Where it seems indicated to Perelman, he makes use of concepts from cognitive psychology to justify his position, but he overlooks that the self-same cognitive psychology has also researched the factors that impede learning, and has emphasized the important role of the teacher as role model and of interaction in the peer group as an instance of socialization. School and teachers do at least not just give in to Perelman. Perelman seems to regard the teachers' resistance as similar to the engine drivers' fight for keeping a second man on the engine despite electrification: »In a feckless spasm of self-preservation the National Education Association proclaims the use of information technology for learning, without a teacher, as a heresy. NEA aims to legally prohibit the implementation of distance learning or computer-based instruction without a featherbedded union teacher present and in control« (116).

International Rankings

Supporters of computer aided learning like to cite international rankings of school performance in order to demand an increased use of new technologies in school. In international rankings on success in school, the USA rank behind countries like Canada, Britain, France, Hungary etc., who are not blessed with computers in the same degree as American schools. But is it justifiable to invest everything in the hope that the poor position of American pupils in international comparisons might be improved by computer technology? Schrage (1994) comes to realize from international comparative studies that »Computers are irrelevant to the quality of education […] Not one of the countries with higher performing students relies on computer technology in any way, shape, or form. Somehow, the students in Italy, Taiwan, and so forth manage to do well without being connected to a multimedia Intel chip or wired to an Apple-generated mathematics simulation«.

Positive evaluation results on computer learning are put down exclusively to the Hawthorne or novelty effect by Schrage, to »new attention being paid to the students that has made the difference«. Quite contrary to Perelman, he ends up demanding to ban computers from schools: »If we really cared about a successful public school system–which we clearly do not–we would forbid computers in the school and force educators, parents, taxpayers, and teachers to face reality. We can't profitably computerize our problems away«. He also warns against a computerization of non-technical subject matters. Considering past experiences with computer learning, one must agree with Schrage: The success of authoring systems was non-existent. The success of interactive laserdisc systems never happened. After a longitudinal study in 1988 using 40 major laserdisc projects, more than half of the participants discontinued using the systems. Gayeski (1992) directly puts this down to the quality of the programs.

Betting everything on learning with computers in networks would imply gearing learning, reasoning and communication to subject matters and processes that can be computerized and communicated in that form. Approaches that are exclusively based on technology, like Perelman's, overlook the hermeneutical aspects of knowledge acquisition. We must not overlook the fact that other dimensions of personality, like motivation, creativity, and sociability, contribute to the development of the ability to learn, and neither must we overlook the component of model learning which requires a teacher. As will become clear in the evaluation studies on computer learning to be discussed later, the decisive variable for learning success is not the program, but the teacher who can fill his or her pupils with enthusiasm for working with that program.

The Teacher is the Key

Perelman's premise contains another argument which he unfortunately does not take up once in his entire book: he seems to have unlimited trust in the quality of hyperlearning products. As I am going to demonstrate in this book, however, both light and shade are well distributed over this area. Today, the number of programs that teachers might sensibly employ in school is easily calculated. The decisive role of the teacher, be it for good or bad, is stressed by Fosnot (1992): »I have seen well-designed materials and instructional environments […] totally misused by teachers who meant well but who held strongly to objectivist and transmission beliefs […] I've also seen the reverse, like the teacher described previously, who taught a very stimulating and enriched unit with simple materials. The key is the teacher« (175).

Nix (1990) describes an example for a stimulating use of simple programs for enriching learning. He uses the computer as a support for learning, not as an end in itself, but for objectives that go far beyond anything computers will ever be able do understand or do: »The focus of our paradigm is on how the child can use the technology in an expressive way. The focus is not on the technology itself. The goal is to enable the child to be creative and self-expressive using the computer, but in areas that are not intrinsically related to computeristic concepts, and that cannot be expressed computeristically« (149). Multimedia is a new medium and a new communication technology. The justification for learning with multimedia is that aspect of learning and instruction which may be designated as enrichment of learning. Integrating multimedia into traditional instruction – and not employing multimedia as an alternative to instruction – should represent the actual challenge for the designers of learning programs. Perhaps one can reduce the educational functions of multimedia to these core aspects:

- Simultaneous access to a multitude of sources and different types of information (data, texts, pictures, films) is made easier.
- Basic research, which today is done at the student's expense, becomes less of a load; time is saved that can be used for more effective study.

- The wealth of information also results in a confrontation with a multitude of opinions; this can stimulate thought, support reflection, and provoke pluralistic viewpoints.
- Cognitive tools are creative extensions for intellectual work and offer increased opportunities for cognitive constructions.

No End of Questions

Is that all? Or are there pedagogical, educational reasons for positive learning effects of multimedia? Is learning with multimedia a different kind of learning? Does learning with multimedia have a different quality? May we, or must we even claim that learning becomes more effective, and that both amount and quality of that which is learned increase? Generalizable answers to these questions are certainly not valid under any conditions. It is therefore plausible to put precise questions: When, and under what conditions, with what programs, in what subjects, and in what shape is multimedia an enrichment, a valuable addition to instruction, a valuable tool for study?

Despite the excellent technology of Athena and the creative applications developed with Athena, Hodges and Sasnett (1993) arrive at this sobering assessment: »This approach of combining theory with experience does not bring anything fundamentally new to the science of pedagogy – teachers have always taught both aspects of knowledge. What is new is the packaging, which holds the potential for a major advance in students' interaction with ideas« (32). At the end of this book, we will have to ask ourselves whether Hodges and Sasnett are right in their claim that it is just the packaging, or – to use a modern term – the »marketing« that makes multimedia appear as something new to our eyes. At the core of this book will be the question that Mayes (1992a) has formulated as a criticism of the literature on multimedia: »While most of the current literature is about how to achieve multimedia solutions, there has been little work on the even more fundamental issues of why and when multimedia techniques would be of benefit« (3).

News Exchange

USA

The special importance of computer technology for schools and universities and the communication in networks in the US has become known internationally through an extraordinary occurrence: The »Information Highway« played an important part in the first presidential campaign of Bill Clinton and Al Gore. Their plans for a renewal of the »National Information Infrastructure« aim at creating a network of all schools, colleges and universities, libraries, and hospitals up to the year 2000. These are no dreams of technology freaks: Riehm and Wingert (1995) point out the democrats' clear sociopolitical aims behind these technological perspectives. It is not at all the case that there had been no preparatory work for these plans. In the USA, even Congress committees deal with the topic »Educational Technology: Computer-Based Instruction« in official hearings. There is a »Subcommittee on Technology and Competitiveness of the Committee on Science, Space, and Technology«, for example, or a »Computer Science and Telecommunications Board« in the House of Representatives. The latter made a statement on the »National Challenge in Computer Science and Technology« as early as 1988. Another of the most important pioneers is the council of the 57 State School Officers [CCSSO (1994)], which in a resolution of 1991 recommended the use of computers both in school and leisure time [Ely/Minor (1994)].

Die »National Aeronautics and Space Administration« (NASA) has integrated multimedia into its Scientific and Technical Information Program (STIP) [Kuhn (1991)]. STIP sees multimedia as a chance for coping with the rapid expansion of scientific-technical information. An infrastructure must be created for this purpose. It is only logical that the »U.S. Government Printing Office« (GPO) plans to transform itself into an institution for the distribution of multimedia products and services [Kelley (1992)]. The industry is also quick to introduce multimedia. Thus Cantwell (1993), for example, reports Union Pacific's plans for in-company staff training with multimedia [s.a. Tuttle (1992)]; Zemke (1991) reports on the utilization of interactive video training at Shell.

Political Initiatives

Such initiatives are by no means restricted to the USA. In the second half of the eighties, almost all industrialized nations initiated development programs for hardware and software acquisition in schools and universities:

Denmark

The Undervisningsministeriet (1994) of Denmark has formed an initiative for technology supported learning, and called for the foundation of an electronic university [Ringsted (1992)].

Norway

Norway passed a resolution on an action program in 1984: a five-year-program with a scope of 11.3 million crowns, with compulsory education in computer technology. Out of 300 applicants, eight schools were selected for the experiment. Rust and Dalin (1985) give a progress report after the course of five years [s.a. Wennevold (1987) and Welle-Strand (1991)]. They even went as far as to develop their own standard software for user interfaces, for simulations, for graphical Pascal programming, and for interactive literature [vgl. Haugen (1992)].

Netherlands

In the Netherlands, the four-year project INSP for the promotion of courseware development with a scope of 250 million guilders was initiated in 1984. One year later, the NIVO program followed, which was supposed to get hardware for the schools for 69 million guilders. Van der Mast et al (1989) report on the execution and effects of both programs.

Great Britain

Great Britain already set up a commission for the introduction of new technologies into the universities in the early eighties [Gardner/Darby (1990)]. At the same time, institutions like the »Computers in Teaching Initiative« (CTI) were established, which are supposed to accompany and give advice on the effective use of computers in university teaching. Boyd-Barrett (1990) describes British education policy as a clear example of »State-Directed Innovation«.

Germany

With the CIP program (computer investment program) started in 1985, the Federal Republic of Germany wanted to enable universities to pursue teaching with computers. From 1987 to 1992, new computers for 291.7 million DM were acquired, that is roughly

1120 Pools with 17.824 workstations for students. In a second investment program, the WAP program (Wissenschaftler-ArbeitsPlätze = scientists' workstations), a total of 567 clusters with 5300 computers was bought for 144.9 million DM until 1994.

Australia

Hammond (1994) reports on the CAUT commission set up in Australia which allocates grants for the development of software for university teaching.

What does a scenario like the one painted by these political initiatives tell us? Could the politicians involved in these decisions perhaps have been taken in by the Perelman myth? If we may believe Schrage (1994), this is the case. Or is there something after all in the theses claiming an increased effectiveness of teaching and learning through multimedia and network communication? Most probably, these questions cannot simply be answered with either yes or no. This book above all wants to throw some light on the theoretical background of multimedia from a psychological-pedagogical point of view, to achieve a balanced perspective – with regard to such questions as well – and make a contribution to a discriminating argument in the process.

Restrictions and Warnings

There are many excellent books in the field of multimedia and hypermedia, and especially on the concept of hypertext. I do not see any point in writing one of these books a second time. Therefore, this book will not deal with the following topics:

- It does not contain a description of hardware configurations for multimedia, or technical specifications of multimedia data [Steinmetz (1993)].
- It does not explain any of the common standards for video transmission and compression, of the exchange formats for multimedia, or the architecture of multimedia [Maybury (1993)], including object-oriented programming languages [Gibbs/Tsichritzis (1994); Furht (1994), Koegel Buford (1994c) and Fox (1991)].
- Neither does it touch upon database aspects in hypermedia systems, the technical or programming problems of indexing, the automatic generation of hypertexts from texts or conversion of texts into hypertext, or the automatic generation of graphical diagrams from nodes. The automatic generation of presentation designs is considered too specific a topic as well.
- Nor does it deal with current technical possibilities and future developments for digital audio [Strawn (1994)], digital video [Luther (1994b)], audio and video support in networks [Sen (1994)], video conferencing, and operating systems software [on this topic, cf. the contributions in Herrtwich (1992), and in Koegel Buford (1994a)].

- I do not want to aim for the level of technical specification on the topic of »Network and Operating Support for Digital Audio and Video« achieved by the contributions in the reader edited by Herrtwich (1992).
- Neither does the book go as deeply into the hypertext concept as the excellent books by Kuhlen (1991), Nielsen (1990a), or Nielsen (1995b).
- Nor does it offer a detailed description of multimedia possibilities in video conferencing, the World Wide Web [Nielsen (1995b)], the Internet, for video-on-demand, Tele-Teaching, distance learning, or Tele-Shopping [Riehm / Wingert (1995)].
- It does not offer an overview of the development of operating systems and system interfaces that will prove favourable for specific multimedia applications (e.g. OpenDoc, OLE, QuickTimeVR).

There are a number of scientific research questions which would certainly have been interesting to pursue in this book on multimedia, but which had to be left out. Among these are, for example:

- The problem of »computer literacy« widely discussed in the USA and Britain.
- The research on writing processes relevant to hypertext development: creative writing, collaborative writing [Christmann (1989); Bolter (1991)].
- The expansion of multimedia approaches toward collaborative working [Teufel/Sauter et al (1995)], support of management tasks, of decision processes and arguments.
- The multitude of special applications for handicapped people, for »at-risk« students, for senior citizens, and continued vocational education.

Caveats

A few more caveats are in order:

- When I speak of pupils, I always mean students as well, and vice versa. Most ideas taken up in this book, as well as the pedagogical and learning theory explanations employed in their analysis, are not age-specific, but offer stimulation for learners of any kind and any age.
- When users, learners, students, pupils, teachers, university teachers, and other groups are mentioned, these are always meant as sexless linguistic terms covering both known sexes of the human race. I do not want to impede the readability of this book through double pronouns or artificial alternative terms.
- One will hardly escape noting what the Americans call a »bias« in this book. I neither can nor want to avoid this bias (on life, on pedagogics, on theories and methods), but I will try to make it plausible to the reader through argument.

I have to thank a number of people who encouraged me to write and have supported me in my work for this book, who have discussed basic theses of this book with me in intense discussions, and who through their curious questions, motivating suggestions, and critical demands in the past ten years stimulated me into a more detailed analysis of the theories discussed in this book in the first place. I would like to thank all of them without emphasizing any in particular, so as not to run the risk of forgetting one or the other of them.

CHAPTER 2

Multimedia – A Definition

Several Arbitrary Attempts

Multimedia started when the first piano was rolled into a silent movie house. Since then, multimedia, as the term seems to imply, has been defined exclusively as a combination of different media:

- as a combination of text and picture (still frame, animation, film)
- as a combination of text and sound (music, speech)
- as a combination of text, picture and sound.

Even scientists whose names are practically synonyms for multimedia, and who are largely responsible for developments in this field, take the definition of multimedia lightly. For Negroponte (1995), multimedia is simply a mixture of data on a digital basis: »bits commingle effortlessly. They start to get mixed up and can be used and reused together or separately. The mixing of audio, video, and data is called multimedia; it sounds complicated, but is nothing more than commingled bits« (18). multimedia is defined in a similar way by Feldman (1994): »multimedia is the seamless integration of data, text, images of all kinds and sound within a single, digital information environment« (4). According to this definition there would be some doubt whether interactive laserdisc systems should be counted as multimedia.

Data Systems Technology Criteria and Digitalization

These two definitions are mostly based on hardware technology or data systems technology criteria. Multimedia in this case means nothing more than a combination of digital data by a computer, or the technical integration of formerly separate data media on one digital data medium, e.g. a CD- ROM. But with such a definition, the following questions remain unanswered: From what point onwards can we speak of multimedia? With the parallel arrangement of analog and digital sources, like in the laserdisc with two displays controlled by one computer? Or not until the integration of analog and digital media, like in overlaying the video signal on a single computer display? Or even not until we have the originally analog source digitalized in a common data medium environment? Mere digitalization cannot be a valid yardstick for multimedia: even if several media are only presented in digital form, the interaction might be so restricted that the new medium is not significantly different from a video film, which nobody in all probability would call multimedia.

User Perspective: Multisensory Reception

Galbreath (1992) cites several definitions that in no way differ from the ones mentioned up to now. His own definition is also of this type: »It is a combination of hardware, software, and storage technologies incorporated to provide a multisensory information environment« (16). This definition contains two new elements: to the aspect of a mixture of data, Galbreath adds the aspect of the multisensory reception of these data. For him, multimedia is only constituted in the user's perspective of perception. And he speaks of an »information environment«. But the term 'information' remains unexplained here, as in all the authors that lay claim to it. According to this definition, film is technically the best multimedia medium up to now, since it offers fluid pictorial movement with natural sound and leaves the viewer with a lasting sensory impression. But Galbreath again leaves open whether one should understand multimedia rather in the sense of »multiple media«, and whether the joint digital basis plays a part at all.

Information and Message

Just this, however, is the decisive criterion for Grimes and Potel (1991). They criticize that the media are »physically collocated, but not integrated« (49). Grimes and Potel not only look at the physical state of the data, but see the product born of the combination as a new entity: »multimedia creates new information by its ability to juxtapose data that were not otherwise adjacent« (50). Considering that only few applications meet this design demand, they arrive at the provoking statement: »We see a parallel between doing multimedia work today and making a film in 1923«. Nevertheless, they stick to their claim: »Well-integrated multimedia ensure a presentation with a wholeness that delivers a strong, clear message« (51). They provide the best argument for distinguishing between multiple media and multimedia themselves: a multimedia application printed on paper is no multimedia application any longer. In defining multimedia, both the integration of the media and the software are important: »Because multimedia does not only mean that photographs, video, and sounds come together on a CD-ROM; the result must be a binding overall cohesion. Only a meaningful combination supporting a subject matter has any appeal« [Bräuer, cited after Riehm/Wingert (1995), 146]. The aim of this integration is called »message« by Grimes and Potel. If we include technical software aspects in a definition of multimedia, the combination of different media thus turns into an information environment with a »message« to the user.

Computer-Controlled Processing

»Not every combination of media justifies the use of the term multimedia« (16), Steinmetz (1993) warns. He, too, only has the aspect of data combination in mind (17). For him, multimedia only exists in a combination of discrete and continuous data: »A multimedia system is characterized through computer-controlled, integrated creation, manipulation, presentation, storing and communicating of independent information, which is coded in at least one continuous (time-dependent) and one discrete (time-independent) medium« (19). This definition emphasizes a third element apart from the type of data and sensory reception: the control and processing of data by a computer. But the concept of information contained in this definition is problematic: it does not contain any description of the relation of independent information units, merely that they can be combined through hardware and software technology. Terms like multiple media and multimedia are thus not sufficiently distinguished. Another question that remains is why exclusively discrete media should not constitute multimedia as well, why e.g. an electronic book with text and graphics (without sound, or sound that can be turned off), or a Kiosk system with still frames (without animations) should not be called a multimedia medium.

Symbolic Forms of Expression

Although the technical specification of data types seems to be in the foreground for many authors, one can hardly overlook that what is meant is really different kinds of information, because multimedia »involves more than the simple addition of new data types – simultaneous integration of a wide range of symbolic modes into a coherent framework is taking place« [Hodges/Sasnett (1993), 3]. Seen from the point of view of the multimedia developer, the media are symbolic modes of information. Hodges and Sasnett complement the developer's perspective with the user's perspective: From his point of view, the different channels are »modes of expression« (9), different symbolic forms of expression.

Information

The term information is used by many authors in the sense of fixed data units, which are transmitted between computer and user after the model of a simple transport from sender to receiver. Such a concept overlooks that information and knowledge only become active through the user's actions, and only become relevant in the learner's interpretation. A modelling of this process must therefore also include the constructs and reconstructions of the multimedia user. This argument points toward the circumstance that our concept of multimedia apparently also includes the user's interaction with the program: »multimedia systems are not primarily defined by their data structures, but by the nature of their communication« [Mayes (1992a), 3]. In this very spirit, Parkes (1992) calls the term 'interactive videodisc' an »unfortunate misnomer« (97), because interactivity is a concept for user behaviour, not a characteristic of the videodisc system as such.

Interactivity

One aspect of the combination of independent media is overlooked by all the definitions cited up to now: through digitalization and computer manipulation, the sequentiality of the various media is cancelled, their sequence can be manipulated arbitrarily, and because of their integration in the computer, they can be accessed interactively by way of a user interface. The interaction between user and system is thus assigned a very important role: »Interaction is implicit in all multimedia. If the intended experience were passive, then closed-captioned television and subtitled movies would fit the definition of video, audio, and data combined« [Negroponte (1995), 70]. Without this interactive aspect, any definition of multimedia is insufficient. We should always speak of multimedia as an interactive medium.

As we can see, completely different categories are applied for classification: categories from information technology (multimedia consists of documents, multimedia consists of types of data), categories from software technology (multimedia consists of databases and network structures), categories from hardware technology (multimedia is a combination of computer and videodisc). Aspects of information theory are sometimes hinted at (information environment, message), sometimes the user is included into the definition as a criterion (perception, interactivity, multisensory perception). From the criticism of these definitions, the following criteria for multimedia have emerged up to now:

- the data of different media appear in integrated form
- the data are processed and manipulated by a computer
- for the user, multimedia provides a multisensory impression, a multiple representation of information that can be interpreted
- the decisive difference for a distinction between sequential multiple media and multimedia is the user's interaction with the software
- the information presented in multimedia consists of symbolic forms of expression, symbolic knowledge which only gains its value in the user's interpreting action; multimedia information is an occasion for independent cognitive constructs.

If we collect all these aspects in one definition, giving some of them a sharper outline in the process, i.e. that the data are multiple representations of interpretable information, and that the computer merely mediates the user's access to this information, then we arrive at the definition that multimedia must be seen as an »interactive form of dealing with symbolic knowledge in a computer supported interaction«.

Hypermedia

A special problem in defining multimedia arises when the authors start out from the hypertext concept. Yankelovich, Haan et al (1988) see hypermedia as hypertext with multimedia additions: »Hypermedia is simply an extension of hypertext that incorporates other media in addition to text« (81). Mayes (1992a) follows this concept as well: »The latter refers to hypertext-like systems, characterized by their data access structures and differing from hypertext only in their use of other media, usually graphics or video« (3). Hypertext is a text-only system for these authors, while hypermedia – in contrast to hypertext – integrates several media. This would however leave the relation of hypermedia and multimedia an unresolved issue.

Authors that start out from multimedia primarily take the opposite route. For them, hypermedia – in contrast to multimedia – incorporates the basic construction principle of hypertext: »A hypermedia system contains the non-linear chaining of information which in a strict sense must exist in at least one continuous and one discrete medium« [Steinmetz (1993), 357]. Kuhlen (1991) takes a similar view: »The designation 'hypertext' […] currently rather discusses the methodical problems of the delinearization of text or the delinearized representation of knowledge, while the term 'hypermedia' at once evokes associations of the whole technical range of the media employed« (14).

Woodhead (1991) calls hypertext a subset of hypermedia, and hypermedia a subset of multimedia (3). In that case, multimedia would be the all-embracing term, and there would be no hypertext that was not also multimedia. But this is not the case, obviously, because one could not view hypertext as a text-only system then. On the contrary, hypermedia is a subset of hypertext, which is characterized by the fact that it contains not only text but also graphics and sound components [Hammond (1989)].

Nielsen (1990a) takes the opposite route and wonders when a multimedia system becomes a hypertext system: »The fact that a system is multimedia-based does not make it hypertext […] Only when users interactively take control of a set of dynamic links among units of information does a system get to be hypertext. It has been said that the difference between multimedia and hypermedia is similar to that between watching a travel film and being a tourist yourself« (10). A special subset of multimedia, then, is hypertext at the same time, and the decisive criterion is interactivity. If we collate both arguments, we arrive at the following definition: hypermedia is a subset of hypertext, and at the same time hypermedia is a subset of multimedia. It is probably better to view multimedia and hypertext as two independent entities with an intersection that might be called hypermedia.

A New Definition of Multimedia Architecture

Hypertext started with text passages sensitive to mouse clicks. When the first animation programs emerged, a similar principle was realized for graphics: the mouse made pictures move, made characters speak, hypertext became hypermedia. In the object-oriented world of computer programs, texts, buttons, graphic elements, content components, and components of the user interface are all the same in one respect: They are all objects that at a touch can set off a script and thus an action, or send a message to other objects. This principle even applies to digital films: more recent versions of digital films – e.g. Apple's QuickTimeVR – also realize the object-oriented principle. They can be navigated by mouse movements, and they have sensitive areas which at a mouse contact either give out information, or branch to other films. Products working with this technology are called »augmented reality«, an enriched reality in contrast to »virtual reality«, the artificial reality [Bederson/Druin (1995)]. This is because they represent the physical world in the form of video, allow movement in real space, and add information to that reality, e.g. in the form of superimposed three-dimensional graphics as an »annotation of reality« [Feiner, MacIntyre et al (1993), 53], while virtual reality generates the navigable spaces as completely artificial animations.

Object Orientation

One could understand this description as the result of modern, object-oriented programming that does not have anything to do with multimedia at first glance. But this most advanced variant of programming only shows particularly clearly what had been laid out and aimed at in multimedia relatively early. In the days when people wanted to combine a videodisc with a program, but the program unfortunately appeared on one monitor, and the video on another, the integration of film and program on a single monitor and the control of the film through a manipulation of pictorial elements in the film was exactly what the developers were aiming at. They still referred to this technology as »Interactive Videodisc« technology then, in the mid-eighties, and they did not yet say multimedia, but it was multimedia they were speaking of. In the following section, I would like to infer the definition of multimedia from the most advanced stage of development, and attempt a new definition of multimedia and hypermedia with the object-oriented frame of mind.

Multimedia Space

Environment

The architecture of a multimedia system consists of an environment that can comprise more than just the program in the computer, e.g. the class, the teacher, the instruction, and the excursion. We speak of a working or learning environment, and also imply the institutional, social, and communicative context in which a multimedia program is used, while the multimedia system in a more strict sense means the program in the computer. This, again, is an environment in a special thematic context. This environment consists of a visual representation space with graphical objects on the display of a computer, a symbol space with multimedia objects and messages, and an event space of user actions and program routines (user, learner, interactivity, dialogue).

Space: Representation Space, Symbol Space, Event Space

Environment is a term that frequently appears in connection with multimedia applications and in constructivist learning theory, »information space« is a term mostly encountered in hypertext literature and literature on networks or graphical databases [Caplinger (1986)]. I am going to use the term »space« in the following. In choosing this term, I am taking the exemplary realization of the multimedia concept in *AthenaMuse* as a model, in which every application has spatial structures [Hodges/Sasnett (1993), 60ff]. While most multimedia applications today are still working in two dimensions, with static areas in the x,y coordinates of the display, things are constructed three-dimensionally and dynamically in AthenaMuse. I said that the multimedia space consists of a representation space, a symbol space, and an event space: Fischer and Mandl (1990) make a very similar distinction. They distinguish between the surface structure of the hypermedium, its underlying relational and associative structures, and the subjective structure added by the user. I am going to come back to this.

Representation Space

The Representation Space is the level of representation commonly referred to as the graphical user interface. This representation space can have mimetic qualities (isomorphism, representation of real objects, the world, the territory, the scene), it points to a symbol space, a deep structure, its objects can represent abstract entities through symbolic forms, or be purely graphical features without semantics. The multimedia representation space has a spatial (space, location) and/or a temporal dimension (movement, time, story). One might also call it a microworld [but s. microworld definitions which I will go into later]. So far, I see the distinction of representation space and symbol space quite in agreement with the distinction of Dillenbourg and Mendelsohn (1992), who subdivide the interaction space of intelligent programs into a representation space and an event space, and refer to pairs of representation and event as microworlds. The »mapping«, the correspondence of physical and mental forms of representation, is a quite demanding and difficult task.

Symbol Space

The symbol space appears in the representation space as a representational metaphor for abstract or concrete worlds, for the meaning of the representation. From the learner's perspective, it can also assume imaginative, creative or social, political, and psychological dimensions. Implied semantic relations are symbolism, functionality, discontinuity, isomorphism etc. The Americans, never shy of using known images in a new context, have used the term »rhizome« (rootstock) for hypertext or network structures [e.g. Burnett (1992)]. Multimedia architecture has indeed some similarities to a rhizome, a rootstock growing subterraneously at whose enlarged points the actual fruits are produced, while the plant above the earth only shows leaves and blossoms: the symbol space contains the plans and intentions of its designer, implicitly, it also contains the curriculum and learning objectives for the user, and at the same time, it consists of the user's constructs and interpretations, creativity and imagination. Green (1991) probably means something like this when he distinguishes between the surface phenomena of the user interface, and its cognitive dimensions. He criticizes the neglect of the cognitive dimension in Human-Computer-Interface (HCI) research: »Most HCI evaluations and descriptions focus on the surface features: they treat rendering, not structure. Indeed, this goes so far that under the guise of 'cognitive modelling' HCI researchers have generated a crop of papers about how fast can the mouse be moved to a menu item or to a button […] Typically, no mention is made of parsing, conversational analysis, determinants of strategy, or many other central cognitive concerns« (298). I doubt whether the alternative phenomena cited by Green represent cognitive dimensions that constitute the user's interpretations. Green chooses typically psychological criteria for user behaviour: Viscosity, Hidden Dependencies, Premature Commitment, Perceptual Cueing, Role-expressiveness. If we see the symbol space as a space of information or of symbolic forms of expressions, whole worlds of criteria are missing again.

Mayes, Kibby et al (1990) distinguish between multimedia presentations and multimedia interfaces. It is only the communication between learner and system that constitutes the value of the multimedia environment. Such an assumption also explains the serious difference between presentations and interactive multimedia programs for teaching and research, treated separately as they are in this book. De Hoog, de Jong et al (1991) take this one step further. They distinguish the modes conversation and model in the »space of interface« [cf. the term of »design space of interfaces« in Frohlich (1992)], and assign different user interactions to them as input and output conditions.

Event Space

The event space is often referred to as interface or learning environment. These terms are usually treated as interchangeable categories [Nesher (1989), 188]. They designate isomorphic or homomorphic environments for information units that may vary between natural environment and formal representation in mathematics, and whose function may be illustrative or exemplifying. The relations between the two environments is ensured through rules of correspondence. The underlying assumption is that knowledge is domain-specific, while intelligence is domain-independent. In order to distinguish my definition form earlier approaches, I refer to the interface as event space, in which the user's interaction with multimedia objects occurs. Two dimensions result from this, that of the user or learner, and that of the interaction or communication with the program. I am going to discuss the learner in a separate section of this chapter (»The Learner's Role in Multimedia Systems«), and Interaction as well (»Interactivity of Multimedia Systems«). I merely want to introduce the distinction here, which will save us an analysis later.

In terms of programming technology, the event space is nothing more than an »event cycle« waiting for low-level events and reacting to them. I am not concerned with this technical level of interaction in this book. The event space has both spatial and temporal aspects. When Allinson (1992b) defines navigation as the »activity of moving through an information space« (287), and calls this navigation »a sequence of purely physical events«, he means exactly this, that from the perspective of programming technology and computer technology the event space is a physical intervention, which however enables navigation in the symbol space on a higher level. Such categories are reminiscent the classification of the computer as a physical, logical, and abstract machine [Winograd/ Flores (1987)].

Symbol Space

The event space offers access to a world of data, to information, or to the semantic level, the symbol space. In the latter, physical interaction turns into semantic interpretation, the meaningful »navigating« controlled by subject matter, intentions and objectives, that which is known as »browsing«. It is this dimension of the multimedia space that interests me above all. Interaction is the decisive element in connecting representation space and symbol space, without it, no information, or more precisely, no meaning is transmitted. It is only in interaction that the meaning of the multimedia objects is realized in the interpretative act of the user. Roth (1997) points out that »computers are systems which – at least up to now – execute exclusively syntactical operations, whose meanings are only constituted through the human user.« (28) But if the meaning of multimedia objects is only constituted in the communicative interaction of the user with the program, then the pedagogical-methodical design of this interaction assumes a decisive importance. This not only says something about the relevance of interaction in multimedia, but also opens up the event space for pedagogical intentions, intervention and interpretation. The event space is thus always also a learning space for the user.

Multimedia Objects

A multimedia object belongs to both representation space and symbol space, and to the event space as well. It thus consists of an interactively manipulable surface object (foreground, representation) that reacts to actions and has methods that are triggered off by respective events, and a semantic deep structure consisting of the qualities ascribed by the author or user. McAleese (1992), who distinguishes surface knowledge, which is distributed in the hypertext network, from deep knowledge, which is represented in the nodes (14), probably has something similar in mind.

Objects in multimedia are visual or acoustic objects representing the concrete or abstract. The scientific designation of these objects varies according to the perspective from which they are viewed. I will give only two examples of many, in order to sketch that such versions quickly become so specialized that they have hardly any meaning for our context:

- From the point of view of object-oriented programming [Steinmetz (1993)], the multimedia object type consists of ‘compound multimedia objects’ (CMO), which are in turn made up out of CMOs and ‘basic multimedia objects’ (498). Media can be understood as classes in the spirit of object-oriented terminology according to Steinmetz (491ff); he also understands communication-specific metaphors as classes.
- Bornman and von Solms (1993) make use of artificial intelligence terminology in order to characterize multimedia objects: multimedia consists of »frames« and »slots«, and the objects can inherit and pass on their characteristics (264). Frames may be ordered hierarchically and taxonomically, and form classes and super-classes. Relations are formed through attributed or operations and procedures.

The Surface of Multimedia Objects

The surface of multimedia objects belongs to the representation space. As a rule, it consists of graphical representations of deep objects like text, numbers, graphics, sound, music, picture and film, but also of relations and procedures. The surface objects have their own characteristics and methods (e.g. moving icons), which may differ from the characteristics and methods of the objects represented by them.

The objects in the representation space are usually text objects or button objects, but also graphical objects like diagrams and pictures, with paths and polygons occuring less frequently [Casey (1992)]. The surface structure is made up of graphical objects like fields, cursor, buttons, icons, labels, pictures, diagrams, and maps. Their graphical appearance often has a special functionality for user navigation. Buttons may be embedded or exist as separate visual entities, they may have labels or appear as small icons: »If the intended meaning of a button is expressed graphically, we speak of an icon« [Irler/Barbieri (1990), 264]. Irler and Barbieri call the text buttons frequently used in hypermedia applications »intrusive«, and argue in favour of »embedded menus« for hypertext applications [cf. Koved/Shneiderman (1986)]. Vacherand-Revel and Bessière (1992) see graphical representations as especially favourable environments for discovery learning (62).

Deep Structure of Multimedia Objects

The objects in the representation space point to objects in the deep structure, to media. Media may be text, picture and sound (seen from the computer's perspective), or language (text, digitalized speech, language synthesis), music (synthetical, audio), picture (graphic, photo, video, visualization). But the term medium can be applied much more widely: text may comprise alphanumerical and numerical data, and forms of text design, such as a table of data. Pictures may be non-manipulable figures or graphical, manipulable objects. A spreadsheet may thus be a medium, but the interaction between the values in a table and their representation as a scatter plot may be a medium as well. A card or a window is a logically distinct information unit; a button represents an event that causes a change in the currently displayed information. The contents component of the current information unit can be text, picture, sound, language, or program code. Legget, Schnase et al (1990) distinguish between »information elements« and »abstractions«, and see cards and folders, frames, documents, articles, and encyclopaedias as abstractions already.

Media

Media may be distinguished according to the degree of interactivity they allow: linear media, feedback media, adaptive media, communicative media [Jaspers (1991)]. Media may be static or dynamic [Vacherand-Revel/Bessière (1992)]. Text, numbers, and graphics are static. Animation, speech, music, and video introduce a dynamic, temporal dimension. Time exists in two forms in multimedia, as sequence and as real time. And finally, media may be differentiated according to the cognitively relevant characteristics of their respective technology, the manner of their symbol systems, and their processing capacities [Kozma (1991)]. In this spirit, Blattner and Greenberg (1992) comment on the function of non-language sounds, and distinguish as functions of music: »absolute, programmatic, social and ritual, modifying behaviour, and communication of messages« (134). Horton (1993) describes the visual representations of 14 figures of speech in a similar manner.

Multimedia objects in the surface structure stand in a certain relation towards one another, which can be meant as next-to-each-other, one-above-the-other, parallelization, juxtaposition, hierarchization, or succession (temporal relation). In the deep structure, the objects enter into other relations, which one might call demonstration, illustration, commentary, example, reference, causality, indication, narration, argumentation, etc. Hypertext systems, which use so-called »typed« links, try to assign such meanings to text links, to introduce an aspect of the symbol space into the representation space, so to speak [e.g. Hannemann/Thüring 1992].

The distinction of surface, meaning, and method perhaps makes Parkes' (1992) argument that a multimedia system only knows something about the storing of material, but nothing of its contents (98), appear in a different light. This may be true for the individual objects as such, i.e. for the film, the sound object, the text, which themselves have no knowledge of their meaning, but it does not apply to the system as a whole which is meant to represent and construct this very meaning with its structure. But the distinction is a clear indication of the relevance of supporting multiple representations for learning. Since learners generate their own representations and interpretations in dealing with the computer, it makes sense to support this process through multiple representations.

One cannot differentiate between various types of multimedia or hypermedia applications by looking at just the surface structure. It is the shape of directed graphs in the deep structure that is decisive here. If the objects are networked in the form of nodes and links, we speak of hypermedia. Links consist of the actual links and the »link anchors«. Anchors can be represented as buttons, as modified cursor, or as mark-up text.

The relations might also be modelled as a simple or coloured Petri net, as a generalization of existing hypertext concepts with simple directed graphs, or competing paths: »A hypertext consists of a Petri net representing the document's linked structure, several sets of human-consumable components (contents, windows, and buttons), and two collections of mappings, termed projections, between the Petri net, the human-consumables, and the design mechanisms« [Stotts/Furuta (1989), 7; Stotts/Furuta (1988); Stotts/Furuta (1990)]. The structure of the directed graphs decides the type of multimedia or hypermedia application:

KIOSK Systems

- Kiosk systems (chapter 9) merely contain lists of products (table of contents and index), perhaps sorted according to product types, and then branch in the form of a star. There are no further nodes branching from the last elements of the star, so that the user must retrace the path of the graph he has followed.

- **Guided Tours** Guided Tours (chapter 9) may have more complex graphs that can also follow a ring path, but as a rule follow a similar structure as Kiosk systems, i.e. a clear sequence of nodes leading into dead ends from which the user must then retrace the graphs.
- **Hypertexts** Hypertexts (chapter 7) on the other hand are not limited to the structural principle of sequentially juxtaposed nodes, but may realize any reference structure.
- **Electronic Books** This is not the case for electronic books (chapter 8), which constitute hypertext on the basis of the traditional book form, and must limit the range of possible connections in that interest.

The Function of Pictures

There is a whole research branch on the function of pictures in texts and learning programs. Issing and Haack (1985) distinguish between illustrations, analogous images, and logical images. They claim a long-term effect of pictorial forms of coding (115). Pictures are schemata, scripts, and mental models [Weidenmann (1994)]. They serve as

- expression of individual experience
- learning control
- illustration to lend clarity to difficult concepts
- stand-in for reality.

The Function of Sound

Sound in multimedia can remain limited to the surface level, have no semantic function, and noinetheless be important for the acceptance of the application. Chadwick (1992) illustrates this with an experiment in the New Mexico Museum of Natural History: They simply detached the audio output of the multimedia system on display for a week. It was found that the quota of visitors staying with the program from start to finish sank rapidly. This effect would probably not have resulted if text and sound were redundant. In order to clear up this question, Barron and Atkins (1994) tested the influence of text and audio redundance (the doubling of information in two media), and concluded that the doubling had no influence on learning success. Multiple media, simply doubled media, have no special effect then. The functionality of speech must meet with a specific situation, the role of the respective media in multimedia must be seen in the media's differentiating function.

The Methods of Multimedia Objects

The methods of multimedia objects are author-set, permanent, or user-defined, temporary methods, by way of which the objects react to automatic or user-generated events. The forms of manipulation can be indirect and direct, symbolic and manual interactions. The channels used by objects to transport information can be auditive and visual. Objects reacting to interaction exchange messages with other objects. Frequently, the mediation of information follows a hierarchy of objects, as for example in *HyperCard*, which checks whether a message is executed directly, directed towards another object on the same card, to the card itself, to the stack, and finally to *HyperCard* itself, or even from there to a certain object in another stack. Some examples for this:

- The button >Continue< switches to the next card. In doing that, it triggers off a script that performs a visual effect and a sound, makes one field invisible, and another visible.
- The button >Play< calls up a film and plays it.
- The button >Music< plays a piece of music from the CD.
- The button >Compute< sends a message to another card, collects data from that card, inserts these data into an invisible container, a variable, then calls up a script from the stack that computes statistical figures from these data, and inserts the result into one or more fields on the initial card.

Objects in the sense of multimedia configuration are also devices conected to the computer which are responsible for input or output. More sensible definitions of these classes as objects in the light of the object-oriented paradigm can be found in Steinmetz (1993) and Gibbs and Tsichritzis (1994).

The Dimension of Meaning

The technical combination of the media is a necessary, but not a sufficient condition for the definition of the term hypermedia. I prefer to use the term integration, technical and data-technological integration, but also the integration of the multimedia space levels. If we do not consider the distinction between representation and symbolic level in a purely formal way, then the combination or integration of the media in a multimedia system must also include a dimension of meaning for learning: a multimedia application should show some functionality for learning, it must have a meaning, an added value for learning. The added value can lie in factors of reception or learning psychology, e.g. in the updating of several channels in learning, visualization of abstract circumstances, anchoring the coding of information using several senses, or the dynamic representation of processes and events. But the added value can also consist in the learner's cognitive constructs and interpretations stimulated by the multimedia environment, in the mental processing of imagined contents. Contextuality, and seeing the subject matter in the wider context of environment, society, and history, and its interpretation by the learner belong here. Only then does the term »Sociomedia« coined by Barrett (1992) become understandable. I would like to mention some examples for the media's dimension of meaning, which I will discuss in detail later on, in order to explain what I understand by multimedia's dimension of meaning:

SimNerv

In *SimNerv*, one can look at pictures of frogs and listen to their croaking. This takes place in a program that offers students of medicine a virtual laboratory, in which they can execute physiological experiments with frogs' nerves for which, fortunately, no frogs have to be killed anymore. The laboratory and the frogs are separate parts of the application which do not have any concrete relation to each other. The meaning of this combination lies in the justification of the artificial laboratory, it is meant to motivate the substitution of the frog experiments by the artificial laboratory.

Dictionary of Computer Terms with Signs

The *Dictionary of Computer Terms with Signs*, which I will discuss in detail in chapter 8, integrates encyclopaedia texts on computer terms with the corresponding signs used by deaf people in the form of films in a hypertext environment. The user may search for certain terms as well as for certain features of signs, which could not have been realized in book form.

Beethoven's Ninth Symphony

A program accompanying an audio CD opens up *Beethoven's Ninth Symphony* (The Voyager Company) in two different ways: In one mode, the musicological interpretation accesses certain parts of the music, in the other mode, the explanations appear synchronized to the music playing. Interactivity is thus introduced into something that can usually only be experienced sequentially.

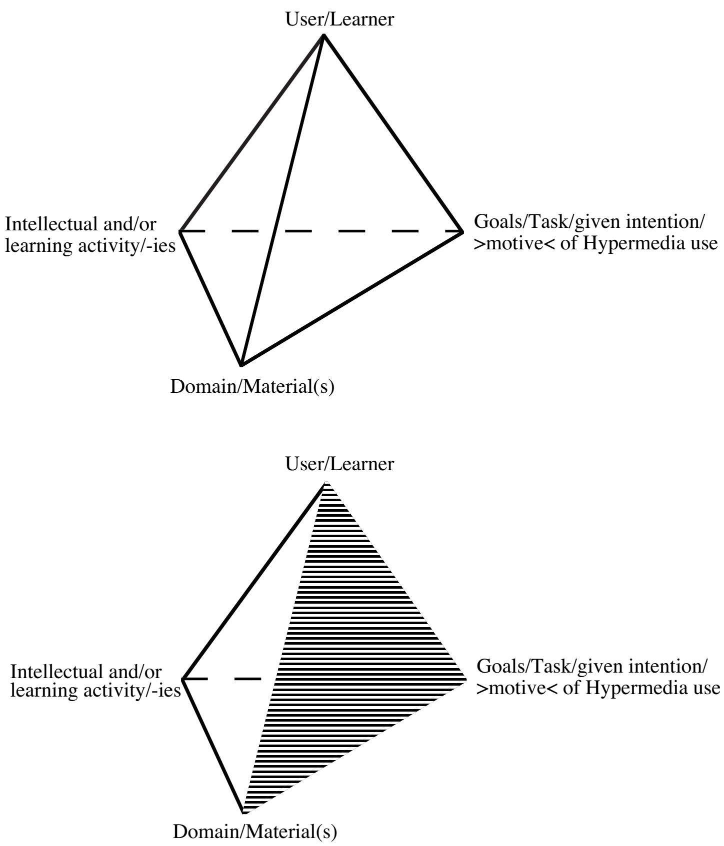
The Problem of Gestalt

In the first case, multimedia serves to motivate a simulation as surrogate for a real experiment, i.e. to justify a form of learning, in the second case, multimedia realizes arbitrary access to a visual language that would otherwise be difficult to learn, in the third case, multimedia makes it possible to experience a serial medium interactively, and networks it with interpretations. In conclusion, I would like to go into another particular aspect of the integration of media, the problem of the integration's gestalt: Should one accept only those combinations of media that make up a new whole, a gestalt, as in the examples just mentioned, or can multimedia also include combinations of media which are combined in a luxurious or even superfluous manner? Is it possible to make a meaningful distinction between necessary and non-necessary combinations? A learning program on film should be able to access the film, a learning program on music to access the piece of music being discussed. But does an encyclopaedia on film history really have to show 10-second-clips of the films? Does an encyclopaedia on music history have to play a groove of each record? In other words: Should the integration of the media show some functionality beyond the obvious, a functionality that lends an additional level of meaning to the subject matter, in order to constitute multimedia? The multimedia applications offered on the market more often than not simply represent a reconstruction of 'natural' (multi-) media on a new technical level. In many cases that which is achieved by multimedia does not go beyond anything that has already been taking place in good instruction with a teacher and several non-integrated media. With this problem, I have addressed a topic that does not have anything to do with the definition of multimedia, but with social criticism of multimedia as a technological trend and market phenomenon. These dimensions of the necessary and the optional are probably difficult to separate in individual cases. But they can perhaps be a useful pointer for stimulating multimedia applications meant to enrich the learning of pupils and students.

The Learner's Role in Multimedia Systems

Alty (1991) criticizes the exclusive stress on the technological perspective of multimedia, the mixture of media, from the consumers' point of view: »Whether users actually want to do this is never questioned« (32). Alty emphasizes a user-centred perspective, and agrees with Elsom-Cook's (1991) statement: »The effort in developing the technology has not been matched by a similar concern with the pedagogy […] At present it is an article of good faith that multimedia is a good thing for education and training. There is no evidence that multimedia enhances learning, or makes it more cost effective«. I will go into the question whether this is an accurate assessment in the chapter on evaluation at the end of this book. What interests me here is the user perspective point of view demonstrated in these statements. To reduce the event space to the dimension of an interface would be to underestimate the importance of the learner and interaction. I am dealing with the role of the learner and of dialogue in this section. In the next section, I will throw some light on certain aspects of interaction.

FIG. 1
Tetrahedron Model by Fischer and Mandl (1990)



Tetrahedron Model by Fischer and Mandl (1990)

One of the few approaches that include the learner in the modelling of multimedia architecture is the Tetrahedron Model by Fischer and Mandl (1990), which distinguishes between the following dimensions:

- the user/learner
- the intellectual and/or learning activity/ies

- the domain/material(s) and
- the goals/tasks/given intention/motive of hypermedia use.

They discuss the four triangular relations or interactions resulting from looking at the tetrahedron's sides:

1. the interaction of learner x goal x domain
2. the interaction of learner x goal x learning activity
3. the interaction of learner x domain x learning activity
4. the interaction of learning activity x goal x domain.

I do not think much of graphical models as a rule, because they tend to disguise problems in the relationships between the individual categories rather than expose them. But in this case I can readily accept the model as a heuristic pointer for the necessary discussion of the role of the learner in hypermedia. It provides a systemic place for the learner's role and stresses the intentions and ideas that the learner brings to learning with hypermedia. The learner's role is related to both the domain and the intended learning objectives (interaction 1). The model points out the learner's goals and ideas which influence his own learning ability (interaction 2). And it points out the interaction between learner and hypermedia object mediated by learning activities (interaction 3). Finally, it defines the »traditional« level of theories of instructions, the relation between domain, learning objective, and learning method (interaction 4).

Fischer and Mandl call hypermedia 'virtual media', because they consist of »subsources«, of partial objects, whose appearance and meaning only come into existence through an act of interpretation. This indication of the reception and interpretation work of the learner, who synthesizes the hypermedia as a meaningful object through his own cognitive constructs, seems very important to me. The hypermedia construct is an abstract entity as long as it exists independent of the user. I do not want to discuss here whether we should therefore, as Fischer and Mandl suggest, develop a »psychophysics« of hypermedia (because psychophysics distinguish between the objective stimulus and its subjective perception, a distinction that is problematic from an epistemological point of view if we follow the theory of Maturana and Varela (1987), according to which there is no objective reality independent of the cognizant subject), or whether it is sufficient to call this aspect user dialogue or learner interaction and to model it accordingly. The indication points toward the common epistemological characteristics of all cultural objects, at any rate, it applies equally to any unread book, any unwatched painting, and any unplayed record. These »sleeping« objects, too, are only »awakened« through the interpretation of the reader, viewer or listener, whom Fischer and Mandl call a 'fuzzy entity'. In this sense, all cultural objects that are only opened up through interpretation would be virtual objects.

The meaningful level of hypermedia objects is thus an object level that is only constituted in an interpretation. To call it an 'abstract entity' for that reason, thus assigning an 'objective structures' status to uninterpreted objects, is at the very least misleading in my opinion. The objects do not have any objectivity outside the viewers interpretations, a fact already pointed out in neurobiology: »The meaning of signals does not at all depend on the nature of the signals, but on the conditions under which they are taken in by the receiver. It is the receiver that constitutes meaning.« [Roth (1997), 106ff] The hypermedia object's dependency on the user points toward the social-hermeneutic dimensions of interaction with programs, and towards the necessity of viewing and modelling the event space as a pedagogical space as well (the term »pedagogical« is not meant in the sense underlying the concept of learning as instruction here).

Learner Modelling

Winograd and Flores (1987) arrive at a similar conclusion in their analysis of expert systems. Since it is impossible in their opinion to model the knowledge of experts in the knowledge component of expert systems, it would be sensible to complement the knowledge model in multimedia systems by a user model or learner model, and to model the multimedia dialogue with the methods of dialogue design and the aid of learning psychology theories as a user model in the form of intentions, plans and strategies. Unfortunately, however, the state of research is not very advanced in this field [Fischer/Mandl (1990), XXIV]. Card, Moran et al (1983), who sketch the learner's interactive dialogue with the computer as a GOMS model (»Goals, Operators, Methods for achieving goals, and Selection rules for choosing among competing methods for goals«), have created a model in the triad of goals, methods, and operators that in my opinion is only suited for the technical dimension of user interactions, which only appear as discrete events for the computer [McIlvenny (1990)]. An extension of the model by linguistic speech acts, sociological dimensions of role-switching, and the power or dimension of communicative action seems impossible to me, and not sensible either.

Interaction Analysis

User modelling in human-machine-dialogues [Kobsa (1985); Bratman (1987)] does not look at the dialogue from a perspective of learning aspects, but rather as a functional interaction with a technological artefact. Approaches to learner modelling for IT systems do not analyse the learning process as an interaction of user and program, but merely as a cognitive model with regard to the respective domain.[1] The speech act theory does not (yet) deal with the linguistically reduced speech acts in communication with a technical interaction partner like a computer [Rehbein (1977)]. And conversation analysis approaches, even if the authors choose information science for their addressee like Wooffitt (1990), have an explicitly sociological focus and do not offer any base for dealing with the interpretative dialogue of a learner with a multimedia program [s. the con-

1. Overviews of user modelling in IT systems can be found in Murray (1988), Nielsen (990), Diaper and Addison (1991), Dillenbourg and Self (1992a).

tributions in the reader by Luff and Gilbert et al (1990)]. One of the few exceptions is Schank and Abelson (1977), who conceive the dialogue with the computer in the form of scripts, plans and goals. Dialogue systems may then be seen as a scenario within which certain language games are played out. The user is modelled through orientation knowledge and action knowledge. The protagonists' actions are described as intentions, plans, and practical arguing [Bratman (1987)], i.e. as intentional acts with a »dialogue partner« restricted to functional interactions, with the term intentional act clearly only meant in the restricted meaning of instrumental intentions here.

Human-Computer Interaction as Instrumental Action

Schanck's and Abelson's model depends, however, on being able to count on a relatively limited domain and as complete as possible scripts for the interaction [s. Minsky's (1992) criticism of 'understanding' in scripts]. This is just what is not possible in human communication, which can at any time clarify the assumptions underlying a communication, and progress into discourse, with the clarification possibly leading to further assumptions having to be clarified in turn. A computer program cannot handle this infinite regression or metacommunication. It must start out from a »fixed set of assumptions« [Suchman (1987), 61]. The user actions are restricted by the program design, the design »assumes, however, that it is the correspondence of the system's plan to the user's purposes that enables interaction« (100). This correspondence assumption takes away space for necessary interpretative acts, because »no action can fully provide for its own interpretation« (67). The analysis of human-computer interaction with plans and goals is an analysis of a goal-oriented event, or of a planning model for instrumental action. It is impossible to arrive at an agreement about statements and action orientations, or even to call into question the extent of the validity of propositions. Such a definition of human-computer interaction as instrumental action perfectly corresponds to the communication theory approach of Habermas (1981) and his distinction of instrumental, strategic, and communicative action (367ff). In instrumental domains, no action that is oriented towards understanding is possible (384ff).

A good part of learning – and also of learning with computers – takes place in dialogue, and this interactive learning is probably the most effective and lasting factor of learning, but there is no theory or model of the dialogue with the computer and learning program on the horizon as yet [Forrester (1991)], much less a concept of dialogic interactive learning.

Human-Program Interaction

There is another dimension that seems to me to have always been neglected in most reflections on computer-human interaction. In my opinion, most models start out too much from conversation or interaction with the computer as machine or tool. But especially if we are dealing with multimedia, we are less interested in human-computer interaction than in human-program interaction. If software plays a part in user modelling, it is usually the operating system, tool programs, or a word processor. A look at multimedia applications, however, which represent a »conversation partner« for the learner, is likely to make the computer as machine or its operating system retreat and become invisible behind the application. Such a view should be able to open up new perspectives, although this is still not a case of communicative action, because the program cannot supply the partner with whom it is possible to negotiate situation definitions, and the program user is the only protagonist who can furnish the necessary interpretations for communicative action.

Constructivism and the Computer

For Maturana and Varela (1987), actions with the computer are merely instructive interactions with structurally determined units (107) corresponding to a simple input-output model, while they demand an independent dynamics of internal relations even for the nervous system (184ff). The idea that the computer (even today) is a machine, and that communication with the computer follows other rules than communication between people, is a widespread one, and has led to a reduction of perspectives on interaction as machine communication, command language, or instruction.

But the overall configuration that we meet in learning with computers is a little more complex, really. More recent positions of the constructivists (I will go into constructivism in detail in chapters 3, 5 and 6) on human-machine-interaction show an intention to apply insights on human communication from psychology and ethnology to human-machine interaction as »shared understanding« [Suchman (1987)]: »The initial observation is that interaction between people and machines requires essentially the same interpretive work that characterizes interaction between people, but with fundamentally different resources available to the participants« (180). The computer is part of the learners' empirical world, and at the same time, it is also a medium for a learning program in which the author has invested certain intentions, intentions directed towards the learner's learning that are meant to more or less »communicate« with, or at least »mediate« themselves to him. The computer is thus no mere tool any longer, but a 'culturally situated object', as Winograd and Flores (1987) emphasize: »An understanding of what a computer really does is an understanding of the social and political situation in which it is designed, built, purchased, installed, and used« (84). Radical constructivist approaches start out from the computer's social embedment and thus do no longer exclude the application of the paradigm of communicative acts to interaction with computers or conceiving this interaction as a discourse model (one must observe, however, that many information scientists no longer use the term »discourse« in the sense of communication theory, but in a sense exchangeable with technical dialogue).

Hermeneutics

With Winograd and Flores, and with regard to the occidental hermeneutic tradition of textual interpretation [or pointing to the current state of computer technology], one may answer the question put over and over again in discussions, whether computers are »intelligent«, negatively, and consider it irrelevant. The negative answer applies to the machine, the physical hardware, from which we must distinguish the program run by the machine, the software, [s.

the clear indication of this difference in Brown (1985), 200]. The other question to be distinguished from the first one, i.e. whether hermeneutic understanding plays a role in learning with a learning program, e.g. a hypertext or an electronic book, can quite simply not be answered differently than it would be if the question referred to the reading of books. The computer has developed from a mere tool, which could be caused to execute certain events with the help of commands, into a device that presents cultural subject matter to the user in the form of texts, pictures, and videos. Dealing with multimedia information must be regarded in the hermeneutic tradition of reading as a matter of course.

Human-Software Dyad

The question, however, whether multimedia, which can sometimes »give life« to books through films and animations, adds new dimensions to this form of reading, is not so easy to answer. Multimedia certainly does not suddenly turn the asymmetrical relation reader-book into a symmetrical, reciprocal relation, a communicative discourse, even if the respective multimedia program could be called »interactive«. Nickerson (1987) discusses this question not on a level of communication theory, but pragmatically, using 16 criteria which for him characterize conversation, e.g. bidirectionality, alternating initiative, presence, a shared situational context and equal status of the partners, arriving at the conclusion: »The model that seems appropriate for this view of person-computer interaction is that of an individual making use of a sophisticated tool and not that of one person conversing with another« (691).

This view is still determined by the tool paradigm of the computer. After what I have just said about the change of paradigm from computer as tool to computer as vehicle of culture, the answer would turn out somewhat differently today: the user deals interpretatively with the subject matter and meanings that the multimedia author's software has to offer. The dimensions that multimedia adds to the book will nevertheless be situated on quite different levels, i.e. those of perception psychology, motivation psychology, and cognition psychology, and not on the methodological level on which we decide on instrumental vs. communicative action, or symmetrical vs. asymmetrical communication, on judgements, and the validity of norms [cf. Penrose (1994), 397]. With regard to these functions one could speak of the computer as a communication tool, a »communication facilitator« [Brown (1985), 199]. That would make clear that neither computer nor multimedia program »understand«. They only understand unambiguous, discrete actions, they do not interpret the subject matter of this symbolic interaction. There is thus no relationship of a human to a »partner«, even if we do not regard the interaction from the point of view of the human-computer dyad, but the human-software dyad [Floyd (1990)].

Mental Models

A definition of multimedia thus consists of the dialogic, interactive component of the multimedia system, and of the interpretation and manipulation of multimedia objects by the learner. The learner triggers off events by manipulating multimedia objects. This presupposes a familiarity with the methods that multimedia objects trigger off in the representation level (ease of manipulation as an objective of multimedia designers). In doing this, the learner makes use of hypotheses about the methods triggered off by the objects in the deep structure. This is why the designers of learning programs would love to get at the learners' mental models, their interpretations of multimedia objects, in order to be able to anticipate or 'harmonize' them in the design [Vacherand-Revel/Bessière (1992), 60]. But all attempts at developing user models have become stuck on relatively low levels of interaction up to now.

Interpretations

The individual interpretations, as well as the individual learning strategies of the learners, are brought into this hypothesis formation, and influence the strategies of interaction with the respective system and the preferment of certain systems, in alternative and free choice, as well as the perception of the multimedia product's structure: »The user's goal or intentions add partial structure to the hypermedium by overlaying expectations onto the hypermedium and its data, a structure which guides the user's browsing« [Fischer/Mandl (1990), XXI].

Individual Styles of Learning

But this is another aspect of interaction that belongs to the underdeveloped aspects of research on the design of the dialogue component or the student models. Research on students' cognitive styles of learning and learning strategies has found little attention, for example[2]. Veenman, Elshout et al (1992) also point out the important interaction of learning ability and learning style or method, and their significance as predictors of learning success. This research has led to a description of individual styles and strategies of learning [Schulmeister (1983)], which can designate factual differences in the learning behaviour of students (deep processing vs. surface processing; holist vs. serialist). According to Laurillard (1979), one must however take into account that the descriptive dichotomies of learning styles are not individual styles of learning, but context-dependent variables. She compared the learning behaviour of students over a sequence of several tasks, in which different demands where put on the learners. Their protocols were analysed using the method of Marton and Saljö, with a 77% correspondence of evaluators. Her study yielded the result that students use different styles of learning for different tasks, and she concludes from this that the characteristic styles are »context-dependent, rather than student-dependent« (407). Even the strategy students choose for dealing with a task seems to be dependent on their interpretation of the environment.

There have been only few studies up to now that researched concepts of learning styles in connection with the effects of multimedia programs and can make an empirical contribution to the discussion just reported. I would like to give a short review of some of these studies in the following (more will be reviewed in the chapter on evaluation, and the chapters dealing with the evaluation of in-

2. Entwistle (1976b), Entwistle/Entwistle et al (1993), Entwistle/Hounsell (1975), Hounsell (1983), Pask (1976), Marton/Saljö (1976a), Marton/Saljö (1976b), Marton (1983), Marton/Hounsell et al (1984).

telligent tutorial systems and hypertext systems), without however entering into the problem here on what kind of learning style constructs the studies are based:

Shute, Woltz et al (1989) tested differences in learning sytles with an ITS (Intelligent Tutorial System, s. chapter 6). They found grave differences. What is interesting about their study is that attitudes changed over time without the tutorial component being able to accommodate this.

Cordell (1991) studied students using an inventory of learning styles (after Kolb), and analysed their interaction with a tutorial that was conceived as linear on the one hand, and on the other hand used branching. Unfortunately, the tutorial is not described in her essay, so that it is impossible for the reader to assess this study's independent variable. Differences between learning styles proved to be insignificant, the methodical variable linear vs. branching however produced clear differences in posttests. This may be due to the fact that the pedagogic structure of the learning materials was not suited to address all styles of learning in the Kolb inventory (this cannot be checked because of the lack of information).

Yung-Bin (1992) studied the effect of styles of learning and instructional advice using a program on DNA and protein synthesis. The results indicated that performance in the posttest, the amount of time needed, and the frequency of selecting embedded information was influenced by the interaction between styles of learning and instruction strategies. A comparison of active and passive learners led to the result that active learners invested significantly more time in the tasks, looked at more information, and achieved better results in the final test.

Stanton and Baber (1992) analysed students with the Embedded Figures Test with regard to field dependence vs. field independence, and had them learn with different training programs, a top-down model, and a non-linear training module. The test was designed in such a way that the learning result was of no importance. It was not a question of which group learned more effectively, but whether the groups that were formed learned differently. This hypothesis was confirmed, but in the end Stanton and Baber themselves offer the thesis for discussion that the concept of styles of learning »may well be an artefact produced by the learners' intelligent adaptation to fluctuating circumstances« (164). They are made suspicious by the fact that »every study of this type emerges with another set of learning styles«. This indication of the meagre and uncertain standing of research in this field of learning styles should indeed be taken seriously. Many of the scales of learning styles used for comparisons have neither received any theoretical foundation, nor have they been sufficiently empirically justified.

Allinson (1992a) analysed students using Entwistle's study inventory with regard to various dimensions (deep processing vs. surface processing, serialist vs. holist strategy) and formed two groups: high reproducing and high meaning. She transferred the *Hitch-Hiker's Guide* to *HyperCard* and conducted an experiment with two different versions. The first version was for the training phase, the second for the learning phase. The only difference resulting between the groups concerned the assessment of the degree of difficulty: reproducing learners thought there was a higher degree of difficulty. But the analysis of the automatically written protocols proved interesting. Significant differences with regard to the use of the index and guided tour mode were found. The analysis of the navigation pointed towards differences in navigation, even if the differences were not significant: »It appears that subjects in Group 1 do conform to the expected pattern, that is showing a preference for a linear and structured presentation of the materials.

Subjects in Group 2 indicated a tendency to utilise the less well structured hypertext navigation« (69). An analysis after four phases of interaction with the material indicated functional differences in using the individual tools: thus utilization of the tour method decreased in the end, while utilization of the map increased.

Lee and Lehman (1993) compared active and passive learners in their interaction with two types of hypermedia: with and without instructional hints. While the learning style variables did not differ significantly, the instruction conditions resulted in clear differences: Both passive and neutral learners achieved better results with the instructional hints variant, while the differences between the two methods proved to be irrelevant for active learners.

Yoder (1994) executed a study comparing learners with a reflective-observant style of learning (n=16) and an active-experimental style of learning (n=42), and arrived at the conclusion that the former learned more effectively with normal video, while the latter did better with interactive video.

A definition of multimedia also includes the intentions and plans that the product designer has invested in the design of the environment, and which are perhaps realized in the user's interpretation. But a definition of the overall multimedia environment also includes the teacher, if the system is employed in a situation that is moderated by the teacher. According to Heywood-Everett (1991), the dominant interaction styles of teacher and school environment also have an influence on the use of computers in teaching. Goodyear (1992) describes the role of the teacher in the multimedia system through the following activities as a form of »knowledge communication«:

- »selecting appropriate software
- planning its integration with other learning activities
- watching over the learners' use of a program
- using the learners' activity at the computer as a window onto their thinking and cognitive development
- summarising, and helping learners reflect on their experiences using the program
- arbitrating disputes and managing the allocations of computer time between learners« (391ff).

Interactivity of Multimedia Systems

Interactions with the computer are actions mediated in a special way. Actions consist of punctuation marks possessing a syntax and a semantics. Seen from the point of view of computer technology, user actions are interrupts of other processes, e.g. the event cycle or a program procedure. It is important to distinguish the physical or technical aspect of interaction from the symbolic aspect of interaction [Dillon (1990), 186].

User interaction with the computer by way of hardware events usually occurs in the form of mouse clicks, i.e. discrete events. Giardina (1992) distinguishes several kinds of interactivity, apparently according to the degree of independence of the learner's actions. I shal try to present a somewhat hierarchical list:

- clicking and pointing
- making notes in hypertext systems (knapsack)
- creating and animating objects
- constructing an effective structure
- working productively.

Singer (1993) studies even selections with the mouse from the point of view of her analogy to functions of natural language, as anaphora, deictic, and ellipsis. But even if we could underlay mouse actions with a kind of grammar of interaction, the actions of an iconic interface user with an enactive character have an extremely fragmentary character from a communication theorist's perspective: a click here, a click there, a brief entering of text, etc. The interaction of human and computer is often regarded as analogous to human communication. This becomes clear if one looks at Herrmann's (1986) analyses of the meaning that interaction and communication assume under different aspects of human-machine communication or social interaction. Floyd (1990) complements this aspect by an analysis of the unsuitable metaphors disguising the fact that this is not a case of social interaction.

From a software technology point of view, interactions are regarded as a form of searching for information or of entering data. This characterization is trivial, it does not say anything, because the intentional and interpretative acts of the user underlying the bit actions are not included in such a technical description of interaction. These make up the actual interaction. Again, we encounter the distinction of foreground and background, or surface and deep structure, just as we did with multimedia architecture and multimedia objects.

The task of a multimedia designer is to achieve an agreement of the user's interaction semantics with the interaction syntax of the program. The so-called »Human-Computer Interface« is finally nothing more than a spatial and temporal form of organisation for the exchange of such syntactic elements. To regard this type of direct manipulation [Shneiderman (1983)] already as a form of conversation [Brennan (1990)] or as »communicative dialogue« [Dillon (1990), 186], reduces the terms communication and conversation to their purely technical or instrumental dimension. How freely terms like communication and interaction are used in the literature is demonstrated by Kearsley and Frost (1985), who distinguish three levels of interactivity in videodisc systems: a videodisc without a program, a videodisc with an integrated program, and a videodisc with a computer program – this means the interaction of system, hardware and software, not between program and user.

Interactivity

Interactivity marks the essential distinction between a computer supported learning program and a film: »The first benefit is great interactivity« [Kay (1991), 106]. Interactivity is not only an objective characteristic of the multimedia system, this characteristic also has a decisive influence on the user's experience: »the design of interactivity in multimedia systems, including the choice of user interface, fundamentally affects the experience of using them« [Feldman (1994), 8]. Even if Feldman recognizes that interactivity is »one of the most obviously unique features« of multimedia (9), he warns of overestimating the importance of this characteristic. Interactivity, according to Feldman, »has become a largely unquestioned gospel [...] often has just the opposite effect [...] becomes too much like hard work and makes users switch off, mentally and physically [...] can be too demanding for some people's taste«. The different assessment of the function and meaning of interactivity is mostly due to the fact that for Feldman interactivity is defined above all on a technical level. If the concept of interactivity only means events like »the mechanical link or the ability to search for images on the videodisc using a computer« [Giardina (1992), 52], however, the user may quickly become bored with interaction. For Giardina, the present discussion about interactivity is »too closely identified with the technological features of the 'tool'« (62). Giardina distinguishes physical interactivity from cognitive interactivity. As soon as one makes this distinction, the program contents and objects assume a more important role for interaction than manual operation. For Giardina, the learner and his motivation move to the foreground, therefore, which calls for consequences in the dialogue quality of interaction in programs (56). Giardina does not come very much farther in the determination of interactivity than to demand an immediate control of visual, oral and written information, because he stops at a definition of »cognitive interaction« from epistemological psychology, and does not consult any communication theory approaches. This becomes more clear in Baumgartner and Payr (1994), when they call the interface a cross-border symbol system (113ff).

Mayes, Dolphin et al (1989) emphasize that science has not as yet come up with any evidence for the efficacy of the typical multimedia components. The lively impression that multimedia has on the user is not a characteristic of the system as such, they say, but due to interaction: »The impact will always depend on an interaction with user characteristics«. Clark (1983), and Clark and Craig (1992) likewise emphasize the aspect of high interactivity in their meta-analyses on computer supported learning: if there are indeed differences found in a comparison of different media, which is seldom the case, they can probably be put down to the chosen method rather than the medium, which, with computer-mediated instruction, would indicate the interaction factor. Gloor (1990), too, sees mostly those characteristics that are related to interaction as the advantages of computer learning programs: increased interaction with the student, individualization, flexible use, increased motivation, direct feedback, simple control of student performance, learner control (198ff). What distinguishes multimedia from all other media is apparently the high degree of interaction, as long as it is utilized by the program designers. Borsook (1991) argues that the best distinguishing feature of multimedia is its potential for interactivity. In his opinion, learning systems should imitate the wealth and flexibility of human interaction as far as possible, and make partners of computer and learner. As conditions for successful interaction, Borsook and Higgenbotham-Wheat (1991) name the interaction's response behaviour immediacy, non-sequential access to information, adaptability, feedback, options, bidirectional communication, and grain size (the size of the smallest unit, s. Ch. 7) (12ff). Gentner (1992) researched continuing motivation of young persons in dealing with computer games through an analysis of programs in which the young people even take strenuous work upon themselves only to be able to solve an adventure. His thesis is that it is a mixture of learner control and external control that is responsible for the young persons' motivation.

Dillenbourg and Mendelsohn (1992) designate the relation of intelligent learning environments and learners as interaction space. This view, which largely corresponds to the distinction of different spaces in multimedia that I have introduced above, does not so much emphasize the internal representation of knowledge on the part of learner or computer as the protagonists' interactions. They divide the interaction space into representation space and event space, with pairs of representations and events constituting their own microworlds.

Design of Interaction

Rhodes and Azbell (1985) distinguish three forms of interactivity design in learning environments: reactive, co-active and proactive design. Reactive design comes from the behaviouristic stimulus-reaction paradigm, while proactive design assigns an actively constructing role to the learner. The distinction is taken up and modified by Thompson and Jorgensen (1989). They situate an interactive model between the poles of reactive and proactive design, a model that allows the learner to browse or select, or the form of behaviour that appears with an ideal tutor. These terms are interpreted by Lucas (1992) on the basis of learning theories. Schwier (1992) also takes up this terminology, rejects the hardware-based concept of »interaction levels« that dominated the literature on interactive video [e.g. Kearsley/Frost (1985)], and describes human-machine interaction as a taxonomy of learner-media interaction. This is based on the type of the learners' cognitive activity. Interaction is described on three levels of different quality:

Reactive Interaction

A reactive interaction is a response to presented stimuli, e.g. an answer to a question that has been put.

Proactive Interaction

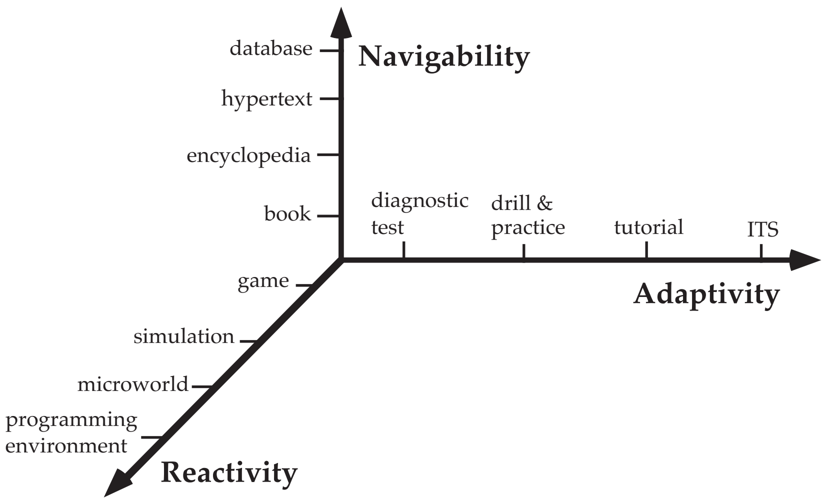
Proactive interaction stresses the constructing and generating activity of the learner. The learner's actions go beyond selecting available information and reacting to existing structures, and generate individual constructions and elaborations beyond the rules set up by the designer.

Reciprocal Interaction

Reciprocal interaction takes place in designs of artificial intelligence or virtual reality, in which learner and system may reciprocally adapt to each other.

Reactive, proactive and reciprocal interactivity are described on five functional levels through the following transactions: confirmation, pacing, navigation, inquiry, and elaboration. One important implication of this description concerns learner control: on the reactive level, the designer maintains complete control over subject matter, its presentation, sequence, and the exercise levels. On the higher levels, rather more control passes into the hands of the user [cf. Schwier (1993a), Schwier (1993b)]. A certain similarity to this classification of the dimensions of interaction is present in the distinction of Midoro, Olimpo et al (1991), who likewise know three dimensions of the interaction space and build a classification of learning programs on that concept: adaptivity, reactivity, and navigability.

FIG. 2 Classification of Learning Programs [Midoro/Olimpo et al (1991), 181]



Interaction is determined not only by the technical dimension of design, but also by the dimensions of the subject matter and the instructional type of software, but it is also partly independent of these factors. Even in a dictionary or an electronic vocabulary book, interactivity can be realized differently than through mere selection of a term. This is demonstrated beautifully by the design for an individual user dictionary by Ferm, Kindborg et al (1987). The learning effect of passive page-turning, or the mechanical following of hypertext links is not assessed very highly: »A reasonable interpretation of the evaluations, however, might be that such a system promotes effective learning only in so far as the users are engaged in actively making their own connections at the conceptual level« [Mayes/Kibby et al (1990), 229]. Wishart and Canter (1988) argue for a classification of software according to the type of software and the degree of user involvement. The consequences of such an approach, which includes the contents of the application in the characterization of interaction, are indicated in Laurel (1989), when she classifies interaction with digital films as narrative, navigational or dramatic.

Giardina (1992) points out the wide spectrum of interaction forms that is determined by the educational ideas of the designers. He grants that one will always encounter designs in which »a particular learning framework is imposed on individuals, based on the erroneous notion that the designer-expert is in the best position to prescribe effective teaching« (54), but basically multimedia allows a design of bidirectional interactivity. Giardina stresses that this form of communication is characterized above all by the control and manipulation that an individual may exert over his learning environment and the objects contained in it [cf. La Follette (1993)].

Interactivity versus Instruction

Jaspers (1991) complains that despite the popularity of the interaction concept, scientific literature does not offer much on this subject (22), and he calls for a new definition of instruction and a concise description of interaction in reaction to Merrill and his concept of instructional transactions (21). This definition should take into account the development that has gained acceptance in Western countries and which is characterized by the fact that the learner is increasingly emancipated from control by the school, the teacher, or the instructional designer: »We must conclude that the point is not: interaction yes or no. The point is: more or less. All the named characteristics of interactivity are gradients« (22). He calls the expression »instructional delivery« a »contradictio in terminis«: »Thus, what we definitely need is a new definition of instruction. Or even more so, a concept that replaces the instruction concept. It is evident that this substitution will make reference to the concept of interactivity«. It is basically irrelevant whether one designates the goal as a redefinition of instruction or as a shift of emphasis from instruction to learning, as the constructivists do. The second version seems clearer to me, because it maintains the traditional meaning of instruction, but demonstrates the principal difference implied in the change of perspective to that of the learner.

Reciprocity and Symmetry of Communication

Jaspers describes the phenomenological level of interaction under the aspects of exchange of information and management of information. He distinguishes introducing a dialogue, setting goals, interruptions, agreeing on the topic, calling for feedback, breaking off the dialogue etc., and finds: »There is equality in all or in a certain number of aspects« (22). The reciprocity and symmetry of communication is that which distinguishes real dialogue from the artificial dialogues of the programs. I cannot agree with a program on the topic which has been predetermined by the author, I cannot cause the program to change its style of interaction and enter into a metacommunication. The reciprocity of communication is violated in human-program interaction. Therefore, Jaspers says rightly: »In fact, we would prefer to reserve the attribute of interactivity for systems in which each partner has the occasion to influence the common stream of events, including the operations of the other partner« (22ff). Stebler, Reusser et al (1994) seem to agree when they say: »The addition 'interactive' is given to those teaching-learning environments in which cooperation and discourse take centre position«. What we need, then, is a cooperative discourse, or, to put it in a more catchy way with Perelman (1992): »The focus is on learning as an action that is 'done by,' not 'done to,' the actor« (23). What is important is that the subject matter is dealt with in a manner corresponding to what Stebler, Reusser et al call »thorough understanding«, with the restriction that this discourse cannot be conducted with the program, but only in the learner's head or in cooperation with other learners and teachers.

Absence of Sanctions in Interaction

In conclusion, I would like to point out another phenomenon that plays an important role in interaction with the computer and a learning program: It is usually overlooked that the interaction with a program is characterized by the fact that it is free from judgement and social consequences. Actions may even be undone without leaving any trace – quite contrary to interaction. Even if a learning program does give out judging statements, I may keep them to myself and can avoid them in repetition. In human-to-human interaction, nothing is retractable, a mistake or an impression once made cannot be deleted. The absence of sanctions in interaction with a computer or program is thus perhaps the most important aspect of the learning subject. One may well speculate that the computer is so attractive to young persons because it gives permanent feedback, but minus the judgement that is inherent in the personal feedback of a teacher. The research results of Rheinberg (1985), who questioned young hakkers about the reasons for their hours of activity at the computer, speak in favour of this thesis. So does Twidale's (1993) observation that students made a lot of intentional mistakes in learning with a tutorial system in order to get tutorial feedback. The interaction of young people with the computer apparently only functions without any fears because one may make mistakes without being punished: »One may suppose that the computer is one of the few competitive fields in which failure-oriented learners are not deterred« [Rheinberg (1985), 98].

This thesis does not at all contradict the observation that computer users usually wish for response times as short as possible, and immediate feedback. On the contrary, short and frequent feedback that causes the learner make a voluntary correction to his behaviour, but remains without consequences otherwise (e.g. no bad marks or moral judgements), is what makes the medium popular. Reinhardt (1995) quotes Schank, who sees as the problem at the core of computer learning that »people need to be able to experiment without fear of embarrassment and with experts looking over their shoulders« (70). The argument thus comes full circle from the topic of interaction to the topics of feedback and student control which I am going to address in one of the following chapters.

What conclusions can we draw from the reflections on the design of multimedia programs that have been discussed?

- One should intensify the interaction options of the programs;
- Feedback must be immediate, especially with mistakes [Larkin/Chabay (1989), 162], so that the learners are informed about their mistake and can correct it;
- One should enable free experimenting with interactive programs.

Structures in Multimedia Programs

Graphical and structural components that give an unmistakable look to the multimedia product represent an important element of multimedia design. Of the many design elements that are used in multimedia, I want to treat four in the following that in my opinion have made a particular contribution to establishing multimedia as a genre of its own: the concept of microworlds, the metaphors, the multiple modality of the user interface, and the components of navigation.

Microworlds in Multimedia

Microworlds are closed artificial environments with rules of their own. Ferguson (1992) attributes the concept of microworlds to Papert (1980) (38ff). It probably goes back even to Minsky and Papert (1972) [s. Minsky (1981) and (1992)]. Papert's Logo and Turtletalk are considered autonomous, but restricted environments, in which one may test certain laws, work with a wide variety of changes in perspective, and construct objects. Squires and McDougall (1986) give a wholly operational definition of microworlds starting out from the foundation of a programming language. In doing that, they ignore the isomorphism problem. Mellar and Bliss (1993) compare the definitions of microworlds in Papert, diSessa, and Lawler. What they all have in common is that they »hide« the knowledge to be learned in the microworld and give students the opportunity of »digging it up again«. Microworlds are explorative learning environments: »Within a Logo curriculum, a microworld may well be conceived of as a play area that gives students a chance to experiment with concepts that do not otherwise exist in the world in that combination« (109). Microworlds are artificial worlds, then, abstract worlds that allow a free combination of possible and impossible concepts. Mellar and Bliss point out, however, that Logo came into being at a time when computer graphics were still in their infancy, and that there are much better graphics programs today, so that that part of the interest in Logo will probably drop. Since the units of knowledge taught in Logo are as a rule smaller than that which must be learned in real life, all that remained would be the effect of explorative learning. But in that case one would have to ask whether the exploring learned in Logo has transfer quality.

What is usually understood by microworlds are smaller, limited environments in physics and mathematics, e.g. one- or two-dimensional movements in ideal spaces [White/Horwitz (1990)], the Turtle graphics in Logo etc. [s.a. Bodendorf (1990), 116], the »yoked microworlds« that couple graphical and arithmetical information [Resnick/Johnson (1988)], the microworld in the arithmetic learning program ARI-LAB by Bottino and Chiappini et al (1994), the coin changing machine in the program Coinland [Hamburger/Lodgher (1992)]. Many of these microworlds start out from a constructivist concept of learning as constructing, like Papert. Logo is perhaps the purest idea of such a microworld, but for that very reason also the most formal and abstract. Rieber (1992) has developed a somewhat more complex example, the program »Space Shuttle Commander«, a software with a microworld on Newtonian laws of movement.

Criticism of the microworld concept comes from the proponents of constructivism, who consider microworlds too artificial: »In many articles, we have found that people like to describe LOGO as a learning environment. Based on our conception of learning environments, we consider LOGO as a programming language, we do not think LOGO is a learning environment« [Chiou (1992), 9].

Microworld as Narrative Structure

Recently, the term microworld is often used in a metaphorical way for iconically closed environments with rules of their own, e.g. for the virtual library, the virtual museum, an invented landscape, a fictitious theatre, a space station, a town. Maps for geographical territories, floor plans of buildings etc. are often chosen for such environments. If one designated any form of artificial environment as a microworld, the term would lose its specific sense. In these iconic environments, the aspects of closedness and simulation that belong to the microworld concept do not play a part any longer. One may basically regard these figurative environments in multimedia rather as a narrative structure of the multimedia programs, which serves to hold together the metaphors used in multimedia programs in a homogeneous way, and provide a basis for navigation control at the same time. Typical examples of this are the building in the mystery game »7th Guest«, in each of whose individual rooms there is a tricky puzzle to be solved, the spacecraft in the adventure game »Spaceship Warlock«, or the control room in Stephen Hawking's »A Brief History of Time«. Such environments have something to tell to the user, they usually contain a story that is meant to make them interesting and can serve as a framework for the individual parts of the program. I have therefore called this a narrative structural element. Their second important function is that of navigation: Such an artificial environment offers a limitation of navigation in a natural way, without reducing the multimedia environment to a simple Kiosk system (s. chapter 9).

Microworlds: Metaphors or Myths?

One might also call such expanded microworld concepts myths. Myths are the archetype of narrative, after all. But Barker (1992b) has chosen another interpretation for these terms. He distinguishes between metaphors and myths as follows: according to him, metaphors and myths differ with regard to the degree of general meaning they possess: »A metaphor is a very general design concept whereas a myth is specific to an particular application« (87). In Barker's opinion, metaphors provide representations for what Barker calls the surrogate principle in multimedia: Fictitious walks, artificial laboratories, role play, and simulated sports (85). Along these lines, he judges that the most often used metaphor is the metaphor of travelling [McKnight/Dillon et al (1992), 82; s.a. Hammond/Allinson (1987)]. I would like to take back this specification in the definition of metaphors, myths and surrogates, and regard as myth the more general, the narrative environment in multimedia, and as metaphors the more specific, the representations of individual objects, ideas, and processes within the myths.

Metaphors in Multimedia

It is conspicuous that multimedia programs use a multitude of metaphors. This starts with the operating systems that take their origin from Xerox's Star Interface [Smith/Irby et al (1982)] and represent their contents as briefcases, trash can, and in windows: »A famous metaphor is the desktop – initiated by Apple« [Späth (1992), 44]. And it ends in environments like »Book House«, a user interface for literature constructed on the basis of cognitive task analysis, which even introduces metaphors for types of literature and searching strategies (by topic, reading level) [Pejtersen (1989); Nielsen (1995), 115ff]. Metaphors are intended as a means of making the user's mental models correspond to the model of the program, and to regulate interaction by way of that correspondence [on analogy s. Gentner/Stevens (1983)]. One would definitely have to settle the role of isomorphic and partly isomorphic analogies for real world phenomena [Streitz (1988)], as well as the assumption that »Analogies between the real world of an hyperdocument and the real world or a scientific theory which is to be studied, facilitate for the users, as long as a good metaphor is chosen, the construction of a mental model« [Oliveira (1992), 6]. An expanded interpretation of the meaning of the metaphors in hypermedia environments would have to consider the interpretation of metaphor by Lakoff and Johnson (1980), as a reflection of the fact that human reasoning processes are largely metaphorical [for a basic treatment of metaphor from a linguistic perspective: Ortony (1991)].

Metaphors in multimedia environments also serve the spatial and temporal orientation of the learner. Metaphors are meant to create a meaningful cohesion of the multitude of information in the multimedia application, and to facilitate the learners' navigation. They provide a symbolic representational framework for that which is usually called »user interface« in the world of computers [s. Carroll/Mack (1988)], and which today is usually clad in the metaphor of the desktop. How important it is in this context to find an exactly suitable idea for the world to be represented is demonstrated by an example discussed in Jacques, Nonnecke et al (1993), a CD-ROM on Shakespeare's life and times with the play *XIIth Night*, which builds its entire design on the world of the Globe Theatre. Jacques and Nonnecke criticize this application as an example for the wrong use of a metaphor that only leads to confusion: »First, the spatial arrangement of seats in a theatre have very little to do with the substance of the play (or in this case, the content). Second, apart from belonging to a particular section (in the sense of the content), a particular seat could not be identified with any particular piece of content. Third, the author did not employ any of the usual cues for seat-finding in a theatre in the navigation tool« (233).

Such an example makes clear: the metaphorical framework must correspond to content and subject matter. In the following, I will name some examples for metaphors that have been chosen in multimedia applications, in order to provide an impression of what a wide field there is for the design of the user interface in multimedia using the design element of metaphor or myth:

Metaphors of Local Space

The map (»From Alice to Ocean«, Magnum Design), the nature reserve, the town, the building serve as topographical metaphors: the ECODisc (BBC) locates a surrogate travel in a virtual conservation area; the town metaphor is chosen by de Moura Guimarães and Dias (1992) as a scenario for the virtual computer; a zoo provides the background for an arithmetic learning program, a monastery is used for an introduction to the middle ages, as in Eco's »The Name of the Rose«, Shakespeare's plays are introduced via the image of the Globe Theatre; geographical maps appear in Fielding's Joseph Andrews [Delany/Gilbert (1991)] and in the Perseus project [Crane/Mylonas (1991)]. Frau/Midoro et al (1992) use the metaphor of a museum for something quite different, namely a program with interactive videodisc on the topic of »earthquakes«; the atlas of the human body provides access to human medicine (A.D.A.M.); museum metaphors occur in applications that want to offer organized access to collections.

Metaphors of Temporal Space

The course of Marvin Minsky's career is represented as a map of biographical stages in his life on the CD of his book »The Society of Mind« (The Voyager Company); a calendar of the last seven days before the building of the Berlin Wall is used as a peg on which to hang the story of that building (»Seven Days in August«, Warner New Media); the history of the Gulf War, »Desert Storm« (Time/Warner) is arranged by way of a time line; the European cultural history of the hypertext program »Culture 1.0« offers different forms of time lines.

Biography Metaphor

»Beethoven's Ninth Symphony« was hung on the peg of a Beethoven biography by Robert Winter, the videodisc on van Gogh uses van Gogh's life for orientation (both The Voyager Company).

Travel Metaphors

Travel metaphors appear fairly often in children's books, e.g. in the now famous mystery book »Where in the World is Carmen San Diego?« (Brøderbund Software). Sometimes travel and adventure metaphor are combined.

Adventure Metaphor

A course in French is organized like an adventure in Paris, or one may »Learn French with Asterix« in a comic.

Personal Guide Metaphors

Personal guides (guides, agents, tutors) or historical personages (»Seven Days in August«, Warner New Media) serve to present historical events. The tourist guide is described by Fairchild, Meredith et al (1989).

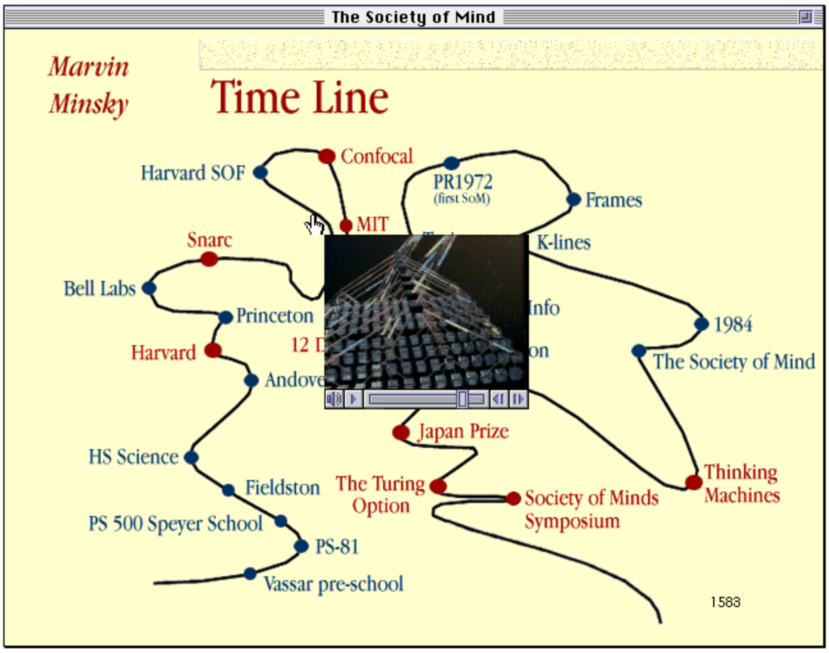


FIG. 3 Marvin Minsky's Biography as Time Line (from »The Society of Mind«)

Book Metaphors

The *Expanded Book Toolkit* (Voyager Company) automatically generates hypertext books out of text files. Several of such electronic books have already been published; one might also consider their introduction into the academic study of some subjects, the works of Shakespeare [Friedlander (1991)], Goethe, and others [cf. the »annotated edition« metaphor in Landow and Delany (1991), 32]. Book metaphors are partly used for purposes that have nothing to do with books, e.g. as an introduction to the medieval world.

Dictionary Metaphor

The dictionary metaphor differs a little from the book metaphor: as an example, I will cite my own »Dictionary of Computer Terms with Signs«, whose contents are solely called up by way of the index or text links [Schulmeister (1993a)]. Landow and Delany mention the »citation index« metaphor.

Metaphors of Virtual Instruments

A compass serves as navigation instrument in the ECODisc (BBC); a cube, the »building block«, as a symbol for the modularity of artificial intelligence, functions as a triple menu in the book »The Society of Mind« by Marvin Minsky; a course on photography is executed with a simulated camera (example in AuthorWare).

Complex systems typically have several metaphors that do not always cover the same image area, but sometimes exist independently of each other. In their »travel holiday metaphor«, Hammond and Allinson (1987) try to coordinate several such part metaphors in a consistent way: travelling alone, travelling with a guide, the map, the index. They evaluate the use of the different metaphors by the learners with regard to intelligibility, usefulness, and navigation, and arrive at positive results.

Metaphors differ with regard to area of application and level. According to Hammond and Allison, a metaphor's area of application refers to the number of concepts the metaphor addresses, while the level designates the level of type of knowledge or the degree of abstraction of the knowledge. According to them, the level has four aspects: the task, semantic, lexical, and physical information (78). It is difficult to make all four fully correspond in metaphors: »the boundaries of the mappings between the metaphor and the system are fuzzy«. Hutchins (1991) [originally 1987] distinguishes three kinds of metaphors: activity metaphors, which are useful in structuring more complex actions, metaphors for the mode of interaction, which help to regulate the mode of communication between user and computer, and metaphors of task areas, which are meant to facilitate the understanding of tasks.

A whole culture of design metaphors is coming into being [Evenson/Rheinfrank et al (1989)]. Bodendorf (1990) describes the metaphor of the book, the library, of travel or guided tour, the compass, the film, maps, networks, and annotations (128ff). Chiou (1992) describes the book metaphor, the classroom metaphor, and the metaphor of a room with various learning resources. For Barker and Giller (1991), the electronic book is »essentially a metaphor – one which is based on people's perception of traditional paper-based books«. Gaver (1986) describes metaphors for audio, so-called earcons, which are meant to represent specific circumstances (e.g. length of message, type of message, and source of message) in a specific way (e.g. direction and loudness of the audio signals) [s. Blattner/Greenberg (1992); Blattner/Sumikawa et al (1989)]. Gibbs and Tsichritzis (1994) also name metaphors for the technical-structural aspects of multimedia, the document, the film, the network, the script or the circuit diagram. There are even metaphors for authoring environments, i.e. metaphors that are present for the author as long as the software is being developed, but which are later invisible to the user, e.g. the theatre or film studio in *Macromedia Director*, the tool box and other tools in ORGUE [Vacherand-Revel/Bessière (1992), 73ff]. Hofmann, Langendörfer et al (1991) even offer special guidelines for the layout of icons and links in diagram windows (442ff). And Horton (1993) even goes back to the poetics of Aristotle for the design process, and distinguished icons according to their inherent metaphors: simile (comparison), antithesis (opposites), metonymy (stressing one feature), synecdoche (letting a part stand for the whole), litotes (double negation), totems, hyperbole (exaggeration), euphemism, synaesthetic analogy, oxymoron (self-contradictory expression), paradox, antonomasia (letting a proper name stand for a function, or vice versa), double-entendre (double meaning), and personification.

Medium, Mediality, or Modality

Mayes (1992a) distinguishes medium, mode, and modality: »A mode in the interactive sense may simply be a dimension of dialogue. Thus the use of a menu might be said to be one kind of mode of interaction, direct manipulation of icons another. Another view would be that a mode is defined by the nature of the information being handled. The modality of an interaction can refer either to the particular sensory system the user is engaging: audition, vision, touch; or it also may refer either to the essentially spatial or verbal nature of the information. A medium, on the other hand, can be any of these, or none. It may be used to refer to the nature of the communication technology« (2). In a similar manner Alty (1991) distinguishes between mode, channel, medium, and style, with mode subdivided into system mode and communication mode (38).

Media and Input Methods

Let us discuss the media first. There is still a noticeable imbalance in their use for multimedia: »The use of sound as a display medium has been comparatively neglected« [Mayes (1992a), 3]. »With the advent of multimedia, however, has come a realization that the haptic channel and the audio channel have been neglected as HCI media« (6). Sound (speech and music) is not usually neglected anymore today (this at least applies to output, not yet to input, e.g. speech recognition), but Mayes' statement is still true for the haptic channel. But here, too, applications are on the horizon: there is work being done on input methods which, apart from the direction of movement of cursor, joystick or data glove, can also register degree of pressure and pass it on to the program, or even transmit feedback of a program's virtual degree of pressure to the user. Input methods are being researched that can pass on impressions captured by the computer to a program: sign language recognition, gesture recognition, tracing of movements, lip-reading, object detection, image analysis. Recent research on image interpretation [Hirata/Hara et al (1993)] aims at having the program recognize both the user and his actions and the user's environment. The most advanced contributions on this topic are found in the proceedings of the »International Workshop on Automatic Face- and Gesture-Recognition« [Bichsel (1995)]. While gesture recognition would let deaf people participate in future developments of the interface, a natural-language interface would exclude them [Schulmeister (1993c)].

Whether the visual mode has an advantage over the auditive mode or vice versa depends on so many different factors [some of them are discussed in Mayes (1992a), 7ff], that it is almost impossible to make general recommendations. One piece of advice remains: use as many media as possible in a redundant way and leave the choice of medium to the user [Bork (1992), 10]. One must however consider that a full redundancy of media does not always prove advantageous, as the experiments with redundant digital audio by Barron and Kysilka (1993) and Barron and Atkins (1994) demonstrate. Edwards (1992) regards redundancy above all as a good means of adapting to users, especially for supporting the disabled: »This is one use of information technology which should not be neglected. Many forms of disability affect people's ability to communicate, but that handicap can be reduced very often by the use of technology which can be adapted to match the users' abilities« (145).

A special computer medium are animations, a combination of still frames and film. Park and Hopkins (1994) recommend the use of dynamic animations with regard to six educational functions:

1. demonstration of sequential processes in learning procedures;
2. simulation of causal models of complex systems of behaviour;
3. explicit representation of invisible functions and invisible behaviour;
4. illustration of a task that is difficult to describe in words;
5. visual analogy for abstract and symbolic concepts;
6. means of getting attention for certain tasks.

Modality

There is a certain correspondence between mediality and modality: a purely textual medium, for example, is unimodal as a rule, i.e. it allows only one form of interaction, namely reading, while multimedia environments automatically use multimodal forms of interaction.

Deictic modality and multimodal user interfaces are treated in Hanne (1992) and Neal and Shapiro (1994), the latter using the military application CUBRICON as an example. The interaction with the system demonstrates an advanced stage of interactive user interfaces: »A user communicates with the CUBRICON system using natural language and gestures (pointing via a mouse device). Typically, the user speaks to the system, but keyboard input is just as acceptable. The use of pointing combined with natural language forms a very efficient means of expressing a definite reference. This enables a person to use a demonstrative pronoun as a determiner in a noun phrase and simultaneously point to an entity on the graphics display to form a succinct reference. Thus, a person would be able to say 'This SAM' (surface-to-air missile system) and point to an object on the display to disambiguate which of several SAM systems is meant« (417). Weimer and Ganapathy (1992) report on a system that combines deictic gestures with speech recognition. Hanne and Bullinger (1992) report on gestural user interfaces with handwriting recognition, which allow the drawing of Hiragana characters in editors for Japanese and Chinese.

A particular aspect of modality is the addressing of the computer by way of natural language. Apple offers such an interface for the Macintosh System 7.5. As the example of CUBRICON shows, however, a combination of natural language and deictics is more advantageous (more effective) than a pure language interface: »The alternative, using natural language only, would be to say something like 'the SAM system at 10.35 degrees longitude and 49.75 degrees of latitude' or 'the SAM system just outside of Kleinburg'« (418). I tend to agree with the conclusion of Hannes therefore: »The most natural means of communication between people is not necessarily the most 'natural' one between human and computer« [Hanne (1992), 160]. It seems more practical to communicate with the artificial creature computer by way of the direct manipulation of objects and perhaps gestures than by natural language [but s. Brennan (1990)].

Buxton (1990) calls nonverbal methods of multi-handed interaction the »natural« language of interaction with a computer. The reason for this may lie in Shneiderman's (1986) argument: »People are different from computers, and human-human interaction is not necessarily an appropriate model for human operation of computers«.

Components of Navigation

An important structural aspect in addition to microworlds, media and metaphors is the so-called browsing or navigation, traditionally called »user prompting«. Using a hypertext system is called »browsing« or navigation, as »navigation through complex information spaces« [McKnight, Dillon et al (1991), 65ff], or as »navigating large information spaces« [Nielsen (1990a), 133ff]. The term browsing (originally referring to feeding cattle) was already a metaphor in the times of reading books. Hypertext systems link texts that are situated on different pages of a book or on different cards of a database system. Considering the multitude of possible links that the user may pursue, navigation represents an especially difficult task for the multimedia application designer.

'Lost in Hyperspace'

The topic of navigation is discussed by most hypermedia authors in close connection with the thesis formulated by Conklin (1987a) that the user might »get lost« in the multitude of information contained in the interaction space, a risk that has been expressed in the catchphrase »lost in hyperspace« [Edwards/Hardman (1989)]. This thesis crops up in many studies, like a biblical quotation. Does it belong to the pedagogical myths that have grown around multimedia? Most authors conclude from this that it is necessary to develop transparent methods of navigation. I think that one can clearly see from the manner in which this argument is brought forward over and over again that the thesis of getting lost serves as a justification of introducing more strict forms of navigation for most authors. It seems to me that this topic therefore has a definite point of contact with the question of learner control, which I am going to discuss later.

Bernstein (1991a) is most vehement in doubting that the phenomenon 'lost in hyperspace' is a fixed one: In his opinion, it is partly due to early hypertext applications, and partly to author mistakes or flaws in the interface design. He mentions examples in which the authors consciously played around with the method of disorientation (290), and is able to detect a positive learning experience in them: »mild disorientation can excite readers, increasing their concentration, intensity, and engagement« (295). However one may define the degree of mild disorientation and realize it in programming technique – I agree with his wish for more exciting applications: »The complete absence of orientational challenges is dull and uncomfortable. A boring hypertext is every bit as bad as a confusing one« [cf. Hannemann/Thüring (1995), 37]. Mayes, Kibby et al (1990) are also of the opinion that it may be sensible under certain specified conditions, e.g. in discovery learning, to offer a certain degree of disorientation: »disorientation in conceptual space is a necessary prerequisite for depth of learning«. They add that »serendipity« is another possibility of guiding the learner (234).

Serendipity

The alternative hypothesis to the concept of »lost in hyperspace« is called »serendipity«, »the gift of making delightful discoveries by pure accident« (Webster's Dictionary): »Sometimes it happens that in searching for a certain piece of information, one is so 'taken up' by another piece of information that the original goal becomes irrelevant or is forgotten over the current dominance of this new piece of information. This is called the 'serendipity effect'« [Kuhlen (1991), 129]. Kuhlen sees an alternative to explorative learning in the serendipity effect. Mayes, Kibby et al (1990) argue in a similar way: There is no harm in getting a little lost, it fosters explorative behaviour [s.a. Macleod (1992), 21].

Disorientation

In their comparative evaluation of three hypertexts, Kahn and Landow (1992) take up the problem of disorientation mentioned by many authors, and first of all clear up the terminology: »In general authors writing about hypertext seem to mean confuse and specifically lose bearings when they use the term, and this usage derives from the commonplace application of spatial metaphors to describe the reader's behavior in a hypertext environment« (64). They demonstrate in this way that the reader's confusion is a product of the design, and does not have anything to do with the materials of the hypertext system. And finally, they point out a learning experience made by many teachers in school and university, namely that students frequently experience something as disorientation (or maybe even only pretend to do so), if they have not understood the logic of certain facts. Kahn and Landow find in such comments of authors the »massive, monolithic problem that these authors pay little or no attention to how people actually cope with this experience« (65), and counter with »expert users of hypertext do not always find the experience of disorientation to be either stressful or paralyzing«. They cite examples from classical literature in which disorientation is a desired effect that beginners experience as disturbing, but experts find pleasurable. They call the latter »serendipity«. In conclusion they stress once more that disorientation »arises both in the normal act of reading difficult material and in poorly designed systems« (76).

One source of »lost in hyperspace« is, and I agree with Landow here, the software's successful or faulty concept of navigation. A disorientation through faults in the navigation is more similar to confusion than to losing one's bearings, to agree with Landow again. I very much doubt whether there is a navigation problem beyond this that is inherent in the hypertext concept. I count this hypothesis among the pedagogical myths about multimedia.

One of the most diligent proponents of this thesis is Hammond, who has filled quite a lot of articles with his idea of a didacticizing of navigation. A look at his writings may clear up the question why this pedagogical myth has grown. For Hammond, citing this apparently plausible hypothesis serves solely to justify his aim of didacticizing the, to him, obviously too liberal hypertext.

That the »lost in hyperspace« hypothesis may owe more to the teacher's fear of having to give up control over instruction than to the structure of hypertexts as such is demonstrated by an example in the report by Veen (1995), about four teachers newly confronted with the task of employing computers in teaching. One of these teachers, the geography teacher, used computers willingly and frequently to support and illustrate his lectures, »he fitted the computer seamlessly into his expository teaching style« (175). But he felt obliged to put a special effort in preparation whenever the computer laboratory was scheduled: »He wanted to keep control over the students' learning process. Students received precise instructions on every step they had to make as 'he did not want them to get lost in the courseware.' He was surprised to find out that students were motivated and quickly found their own way in the software«. Sometimes the pupils' ability for independent navigation is impeded by the dominance of expository teaching because of the teacher's lack of trust in their navigation ability. In this case, everything seems to have gone well. The pupils proved to the teacher that they were better than his expectation.

Segmentation and Contextualization

Another problem that is closely connected to navigation is the segmentation of learning units in multimedia applications, or the atomization of texts into documents or text segments in hypertext systems. Such segmented pieces of information units are called »chunks«. Segmentation is a necessary structural principle for realizing links between the units. One usually works on the assumption: »the smaller, the better«. But if the chunks are very small, a high degree of atomization may occur. Whether this atomization will be apparent to the user mostly depends upon whether the navigational structure »sits« directly on the informational units, or whether it is largely independent of them. Navigation design is one method of counteracting the impression of atomization. Another method of countering atomization is the contextualization of information units [Kuhlen (1991)]. *Intermedia*, according to Kuhlen, is one of the examples in which contextualization seems to have been quite successful: »The atomization of individual units (loss of context) often criticized with hypertext is exactly reversed by intensive contextualization « (200).

Maps and Graphs

One means of navigation support are maps (or diagrams) for tables of contents that represent the logical argument structure, or plot the structure of text unit links, that depict geographical information, or link chronological data in a graphic way. Maps are images of reality; they contain graphical symbols and verbal notes, and physical or logical relations between objects. Maps are suitable for depicting relations between objects of a multimedia environment in such a way that a semantic relation to the real environment of the depicted system results, a situating of the objects in multimedia symbol space. Today, interaction in hypertext and hypermedia systems is usually still restricted to one-dimensional (text, buttons) or two-dimensional objects (maps), and to fixed links. It is to be expected that the three-dimensionality of hypermedia objects will sooner or later lead to the introduction of multi-dimensional open search spaces with physical objects as nodes and so-called »dynamic query filters« [Ahlberg/Shneiderman (1994)]. A system that constructs maps as three-dimensional representations of large databases is *SemNet* [Fairchild/Poltrock (1986); Fairchild/Poltrock et al (1988)]. Spatially designed hypertext nodes are offered by the hypertext tool Aquanet [Marshall/Halasz et al (1991); Marshall/Rogers (1992); Marshall/Shipman (1993)]. A system that depicts its contents as three-dimensional cones, so-called Cone Trees, is described by Robertson, Mackinlay et al (1991) and Robertson, Card et al (1993): Their main goal is the extension of the workspace beyond the limits of the screen; this is achieved by a virtual workspace and spatial metaphors, visual abstractions like walls with boxes and tree-diagram-like visualizations of hierarchical catalogues, as well as by semi-autonomous agents. Animation is important for orientation in such spaces: it reduces the cognitive load and maintains object consistency. In this exact spirit, Apple Computer has presented an interface technology for the World Wide Web in 1996 that displays Internet addresses as islands drifting in three-dimensional space, in which the user may navigate by mouse movements, just as he would in one of the typical space games.

Graph structures or tree diagrams are chosen as graphical representations of the argument structures in expert systems or ITSs, e.g. for the expert system GUIDON-Watch [Richer/Clancey (1985)]. *Intermedia* and *NoteCards* can automatically generate two-dimensional graphical diagrams of the respective hypertext application's structure. Browsers (as in Smalltalk) and maps (alphabetical, hierarchical, network structures, Petri nets) on the other hand are preferred forms of representation for hypertext systems. Whether browser or map is decided by the width and depth of the system. Graphical maps are useful with small systems, for more complex network structures, a browser is more suitable. Jonassen and Beissner et al (1993) describe the entire repertoire of graphical methods of knowledge representation and navigation in their book.

Of course one cannot simply assume that such navigation helps are cognitively better, more intuitive or more natural. That is another research subject. There are several hypotheses – frequently unspoken – behind the attempts of providing maps of this kind for navigation:

Cognitive Navigation

Representations of knowledge structures support the formation of cognitive concepts for navigation.

Semantic Navigation

The use of verbal labels and icons supports a kind of navigation that concentrates less on the outer characteristics of the structure, and rather on the semantic content of e.g. a text.

Geomantic Navigation

The use of geographical maps and other spatial methods leads to an anchoring of information in an additional spatial dimension.

Chronomantic Navigation

Time lines, data lines, and other chronological principles of order give a historical dimension to information.

Cognitive Navigation

What does cognitive navigation mean? The phrase »cognitive maps« for graphical navigation instruments seems to be used on a mere figure-of-speech level by many multimedia authors. McKnight, Dillon et al (1991) pursue this question in greater detail (65ff). They emphasize that we always have schemata or models of the world around us that always allow us to navigate. Their reflections are based on the models of van Dijk (1980) and van Dijk and Kintsch (1983), who postulate macro- or superstructures of functional categories used to understand prepositions in texts. The function of such reference frames for orientational knowledge is, however, according to McKnight, Dillon et al, limited under certain conditions. For that reason, they rather concentrate on the function to learn such cognitive concepts through programs.

The hypothesis of cognitive navigation is researched by scientists who study problems of knowledge representation (»cognitive mapping«) [Giardina (1992), 55ff; Jüngst/Strittmatter (1995)]. Green (1991) researches cognitive dimensions of structural diagrams for the representation of book structures, music notation, and document structures. Woodhead (1991) tends to understand cognitive representations as pure representations of causal relations (139ff).

Semantic Navigation

What does semantic navigation mean? First of all, one must agree with McKnight, Dillon et al (1991), who state: »One aspect of the whole navigation issue that often appears [to be?] overlooked in the hypertext literature is that of the semantic space of a text or electronic document« (85). Their definition of semantic navigation points toward the interpretation of the meanings contained in the application: »In other words, to what extent does a user or reader need to find his way about the argument that an author creates as opposed to, or distinct from, navigating through the structure of the information?« It seems that here we meet again with the distinction already made between surface and deep structure or representational level and level of meaning: On the surface of the multimedia application, navigation follows external forms of representations. But this outward form of navigation corresponds to cognitive principles (e.g. orientational knowledge) or semantic aspects. Correspondence does not necessarily imply here that the concepts of both levels correspond to each other, since the user may work with individual constructs and interpretations internally and only employ assimilation and accommodation when perturbations occur. The learner can only overcome discrepancies in actively coming to terms with the material.

Most hypertext systems that use graphical diagrams do not differentiate node representation according to the type of link, although it would be possible in principle to provide object relations with attributes and represent similar links in aggregates: »However, maps rarely go as far as allocating term weightings or Bayesian probabilities as used in inference nets« (141). I will go into this in more detail in the chapter on hypertext systems.

Navigation by way of icons, picons and micons can be regarded as form of semantic navigation. This means that one tries to increase the meaning of the user's navigation steps through such information. In »Elastic Charles«, hyperfilm combinations of shots of the Charles River were for example realized through micons (i.e. moving icons) [Brøndmo/Davenport (1990); on the *AthenaMuse* video architecture see Michon (1992)]. The wish for more meaningful forms of navigation leads to the reflection, on the other hand, whether one should prevent semantically irrelevant jumps [Macleod (1992)].

Talking of »Elastic Charles«, I must observe here that the use of digital video in hypermedia environments will lead to a more strongly object-oriented navigation based on pictorial information. The necessary prerequisite for this is a linking of images or films without the mediator text. This requires image recognition algorithms that would have to be able to recognize similarities in images [Hirata/Hara et al (1993)]. We do not yet know what cognitive or semantic aspects such a form of navigation implies.

Geomantic Navigation

Geomantic navigation with compass, map, ground plan, floor plan, is meant to support something that might be called a »conceptual geography« of knowledge, as cognitive »territory«. Medyckyj-Scott and Blades (1991), who study the cognitive representation of space in the design and use of geographical information systems, try to get to the bottom of such ideas, as do Hofmann, Langendörfer et al (1991), who study the principle of locality in hypertext. They distinguish the one-map-view, the global map-overview, and the principle of locality, chosen by them for CONCORDE, with the spatial metaphor of neighbouring maps. Neighbouring maps are those maps whose relation is defined by a current focus of interest. Mukherjea, Foley et al (1994) suggest that other structures may be built on the next hierarchical level above the maps, e.g. clusters with clustering techniques, in order to provide an overview of the entire system. Other possibilities are offered by fish-eye views [Furnas (1986)], realized in an exemplary manner in CERN Diorama developed with *AthenaMuse* [Hodges/Sasnett (1993)]. Navigation in speech environments (digital tape recordings) presents a special problem. In order to search for specific aspects, the user must still enter text [Arons (1991)]. More elegant forms are conceivable here as well, e.g. sound files with subtitles that react sensitively to search routines, or speech recognition.

Evaluation of Navigation

Evaluation studies on navigation with maps have not yielded any disambiguous results up to now. Thus Jonassen and Wang (1992) arrive at the conclusion that a graphical browser that represents the knowledge structure and demonstrates the typing of links does not improve the acquisition of structural knowledge in knowledge reception. But clear learning success was established for active knowledge construction. In Nelson (1992), representations of knowledge structures were employed in three groups: The first group used the knowledge maps for reading, the second constructed a knowledge representation without feedback, the third constructed a knowledge representation with feedback. A significant increase of learning was found in all three groups. But the first group did better in the posttest, perhaps because the other two groups were too much distracted in the experiment by the additional task of constructing maps. In all studies on cognitive and semantic navigation, however, the validity of the correspondence hypothesis between cognition and navigational structure is never discussed as a problem, although it is called into question by the interpreting performance of the learners, as I have now pointed out several times. McKnight, Dillon et al (1991) also stress that experiments which try to explain the cognitive processing of graphical means of navigation with the help of information theory models of memory or problem-solving fall short of the mark, because these two structures do not necessarily correspond to each other: »The claim that a simple, non-hierarchical associative net, or web, is an ideal or natural model for hypertext because it mimics human memory must be seen as inadequate« (98). More on navigation in multimedia systems will be found especially in the chapter on navigation in hypertext systems.

Classification of Software Types

Gibbs and Tsichritzis (1994) classify the following types of multimedia applications:

- interactive laserdisc applications
- electronic games
- hypermedia browsers
- multimedia presentations
- multimedia authoring systems
- multimedia mail systems
- desktop video systems
- desktop conferencing systems
- multimedia services
- multimedia operating systems
- multimedia production tools (9ff).

Everything that has do to with multimedia directly or indirectly is gathered here. They throw together operating systems, hardware aspects (laserdisc, desktop video, desktop conferencing), aspects of contents or function (games, presentations, browsers), and tools (authoring systems, mail, conferencing) as well as aspects of infrastructure (services) in a motley collection. In addition, they suggest classifying multimedia applications according to type of composition, synchronization, interaction, and database integration, with composition embracing the following characteristics:

- mechanisms
- spatial composition
- temporal composition
- semantic composition
- procedural composition
- component-based composition (252ff.).

Gloor (1990, 198ff) distinguishes four categories of multimedia programs, clearly with a view to the pedagogical construction of the applications: drill & practice, tutorials, educational games, and simulations. Bodendorf (1990, 48ff) distinguishes programs according to their interaction methods in help (learning by pointers), passive tutor (self-controlled learning), training (learning by exercise), active tutor (guided learning), simulation (discovery learning), game (entertaining learning), problem-solving (learning by doing), intelligent dialogue (Socratic learning). Ferguson (1992) subdivides multimedia forms of learning on a scale according to the degree of learning control allowed by the programs, into drill & practice, tutorials, parameter-based simulations, micro discovery activities, ITSs, microworlds, programming environments, application tools (34). The criterion of learning control as a parameter for a scaling of learning methods is not new (s. chapter 2). One can classify multimedia application either according to didactic principles of construction or the degree of learner control [Schulmeister (1989)]. I would like to distinguish between the following types of multimedia learning programs, with the distinguishing characteristic always one concerning theory of learning, namely the degree of freedom of interaction that the learner is allowed in interacting with the program, vs. the degree of control that the program exerts over the learner, and with a stress on learning programs, i.e. all tools, utilities etc. are excluded:

- drill & practice programs (s. chapter 4)
- courseware (s. chapter 4)
- presentations
- Kiosk systems (s. chapter 9)
- guided tours (s. chapter 9)
- electronic books (s. chapter 8)
- hypertext systems (s. chapter 7)
- simulations (s. chapter 11)
- interactive programs (s. chapter 10)

I do not want to describe the individual categories in detail here, because they are discussed at length in the respective chapters of this book. But a few explanatory remarks are in order: drill & practice programs owe their origin to the behaviouristic model, which works with small steps of learning and frequent feedback. The type of software that is called courseware descends from that model, but has abandoned the behaviouristic concept. Courseware mostly uses frames, fixed learning units that cannot be influenced by the learner. Kiosk systems and guided tours are likewise frame-based, but offer the learner more options of individual navigation. Since they are basically restricted forms of hypertext, they do not offer as much freedom of learning as a hypertext, on the other hand. Hypertext systems allow an active dealing with information, but not the construction of individual hypertexts. Such a type of software is called a cognitive tool and belongs to the class of interactive programs, which ranges from programming environments to working with all kinds of programs. Simulations are often named as an individual category because of their distinctive characteristics; they alternate between the simulation of biological systems, physical laws, mathematical or abstract models (modelled eco-systems or business models), and the simulation of machines (cars, ships, planes), the so-called simulators. Simulation programs belong to the type of interactive learning programs, even if machine simulators are often used for drill & practice purposes irrespective of their design.

Similarities to the scale proposed here can be found in the approaches to a description of learner control by Merrill (1980), Laurillard (1987), and Depover and Quintin (1992):

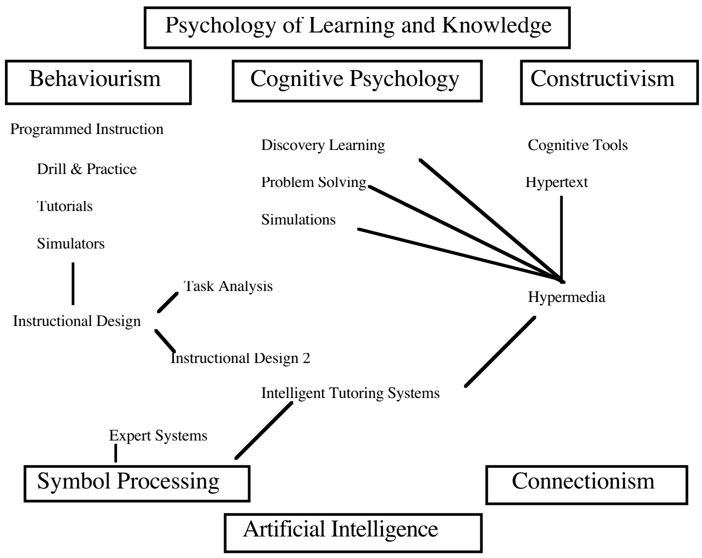
- Laurillard (1987) has introduced the interesting distinction between didactic model and communication model. In the didactic model, the teacher has full control over subject matter and method of learning, in the communication model it is the learner who has control. She distinguishes four dimensions of learner control (domain access, control over exercises, type of feedback, goal justification), which she assigns to program types from the traditional CAL program to intelligent simulations. The traditional CAL program and the tutorial offer least access to the domain to the student, very little operational manipulation in the domain, exclusively extrinsic feedback, and a low degree of transparent goal justification. IT systems offer direct access to the domain, operational control over knowledge and exercises, intrinsic and extrinsic feedback, and transparent goals. Simulations represent a compromise between conventional and intelligent systems.
- Depover and Quintin introduce further differentiations for learner control. Thus Depover and Quintin describe learner control as a continuum, distinguishing control over contents from control over strategy in agreement with Merrill [cf. La Follette (1993)].
- Lowyck and Elen (1993) regard programs from instructionalism to constructivism as situated on a scale of the learner's self-regulation (214ff).
- Schwier (1993a) and (1993b) proposes a classification pattern for multimedia interaction that is based on the degree of control and type of cognitive activity that learners experience in prescriptive, democratic and cybernetic learning environments. Drawing on Rhodes and Azbell (1985), Schwier dis-

tinguishes reactive, proactive and reciprocally interactive levels of interaction. With the respective level of interaction, the degree of learner control varies, which may refer to the following aspects: subject matter of instruction, context of learning, the mode of presentation, optional contents, presentation sequence, extent of exercise, level of difficulty, and level of advice.

I have a feeling that such differentiations rather overtax than help the simple task of the classification of programs. This impression is confirmed when I look at the attempt of Jonassen (1985), who sketches a model for the design of interactive lessons in the form of a cube with 6 x 4 x 4 categories, whose three dimensions he designates as interactivity, internal adaptivity, and external adaptivity, with an additional rising scale for each of the three dimensions. This model, quite contrary to the tetrahedron model by Fischer and Mandl I have mentioned, belongs to the less convincing attempts of trying to create plausibility through graphic models in my opinion [s.a. the attempt of Baumgartner/Payr (1994)].

Software systems that serve as a basis for multimedia are essentially authoring systems, the wide field of courseware, programs from instructional design, intelligent tutorial systems, and hypertext (apart from databases, tools, and communication programs). In this book, I am going to describe these basic types of systems on which multimedia can build – after a short introduction into theories of learning in the next chapter – in order to be able to discuss their pedagogical and design advantages and disadvantages. The following diagram depicts the development of the various directions and their relations to each other:

FIG. 4
The Development of Multimedia Systems



CHAPTER 3

Theories of Learning

The Epistemological Theory of Cognition

Cognitive psychology, which goes back to the theories of Jean Piaget and Jerome S. Bruner, starts out from the assumption, contrary to behaviourism[3] and its theorem of paired associations, that learning is based on cognitive structures and constantly mediated through cognitive concepts. Piaget's theory of genetic epistemology consists of a concept of the organism adapting to its environment that is deeply rooted in biological evolution. The individual's ontogenetic development is regulated through processes of interchange with its environment which Piaget calls »accommodation« and »assimilation«, the accommodation of acquired cognitive concepts to new pragmatic situations, and the assimilation of external objects and conditions into the individual's inner structures by way of a modification of the existing cognitive structures. The aim of these processes of assimilation and accommodation is to overcome perturbations in encounters with the environment, and to create a new equilibrium.

The epistemological theory of cognition has founded two pedagogical-methodical concepts: discovery learning [Bruner (1961)], and learning through microworlds [Papert (1980)]. And it also forms the psychological-philosophical basis of constructivism [s. the contributions in the readers of Forman/Pufall (1988) and Beilin/Pufall (1992); s.a. Varela (1990); Smith (1993)]. I have already briefly discussed the concept of microworlds in the previous chapter, but something remains to be said here about discovery learning. Constructivism will be dealt with in more detail in the following section.

Discovery Learning

The model of »discovery learning« developed out of cognitive psychology: discovery learning emphasizes a cognition process modelled on the heuristics of human reasoning, a process of reasoning guided by concepts, and constructive problem-solving. According to cognitive psychology, learning materials along the question-and-answer pattern allow the learners too little scope for the activation of their existing cognitive concepts and the development of new ones. Tasks which give a lot of room to searching, probing and exploring, as well as the simulation of cognitive processes, are better suited to that aim.

3. In the next chapter, I will deal with behaviourism in greater detail.

What is important for such learning in any case – regarding learning with computers – is the learner's freedom to choose his own paths and strategies in dealing with programs. Jacobs (1992), who laments the lack of history in pedagogics, offers a historical account of discovery learning from Socrates to the present day. In this way, he wants to create a continuity of the idea of discovery learning in history.

Heller (1990) gives an overview of studies on discovery learning. She shows very clearly that discovery learning is no ready-made solution, but that the success of discovery learning depends on many factors: students from a higher socio-economic stratum and urban environments seem to profit more by it, as do self-assured, competent learners, while students motivated by fear of failure profit more by guided learning. But Heller also states that the thesis of discovery learning's motivating effect has been widely confirmed. More recent single studies are, among others

- the study of Wilson and Tally (1991), who examined 10 multimedia programs with a view to their suitability for discovery learning, and
- the study of Wolfe (1992), who wants to promote discovery learning through student-generated experiments in statistics, in order to familiarize the students with statistics and experimental methods, and to foster their empirical reasoning.

As with all empirical studies, there are not only positive results:

- Hsu and Chapelle et al (1993) examined explorative learning processes in a learning environment in which a computer interprets the learners' intentions. The test subjects explored the learning environment expertly, but not creatively.
- Swan (1989) concludes in an experiment with LOGO that instruction and programming with LOGO are superior to discovery learning's concrete manipulations in learning situations with regard to teaching and learning problem-solving behaviour.

Ferguson (1992) subdivides discovery learning into »parameter-based simulations« and »micro discovery activities« (35ff.). I will deal with parameter-based simulations in chapter 11, and refer to micro activities enabling discoveries in several parts of this book. The possibility of practising discovery learning in completely different environments points toward the fact that discovery learning is not so much a learning method as rather a pedagogical attitude with partly methodical consequences going across all types of computer-supported learning software.

What is constructivist about Piaget's theory is the idea that the individual generates the cognitive concepts himself, that the individual only acquires knowledge in an interchange with his environment and that the interchange processes only reach a temporary equilibrium, so that the individual's cognitive development is constantly driven forward by assimilation and accommodation. The idea of these processes provides the motor for the individual's cognitive development and independent learning. Cognition organizes the world by organizing itself. Thus Piaget even saw the mental operations implied in mathematical learning processes as products of spontaneous reconstruction. The child himself generates concepts like reversibility, transitivity, recursion, reciprocity of relations, class inclusion, the preservation of numerical sets, and the organization of spatial reference points.

The principle of the generativity of cognition, which characterizes this concept, cannot be emphasized too often. It is one of the essential foundations of constructivism. And it represents one of the main arguments against the cognitivists' assumption that cognitive concepts can be defined like learning objective catalogues, and turned into the basis of instructional systems.

Constructivism

Constructivism is not a theory of being, it does not formulate statements about the existence of things as such, but is rather a theory of the genesis of knowledge about things, a genetic theory of cognition. For constructivism, knowledge is not an image of external reality, but a function of the cognitive process. The alternative epistemological position, that the world is made up of objects and cognition consists of the corresponding representations of these objects (correspondence or identity hypothesis), which are stored in the mind as objects, is called objectivism [Lakoff/Johnson (1980), 186ff.]. In contrast to objectivism, constructivism emphasizes the active interpretation by the perceiving subject, the process of the actual construction of meaning, in which »every act of cognition creates a world« [Maturana/Varela (1987), 31].

Constructivism, like Piaget, strives for a genetic epistemology which deals with the formation and meaning of knowledge. For constructivism, the meaning of knowledge is based exclusively on the function of knowledge [Clancey (1992)]. The important feature for differentiation from other cognitivist approaches is that knowledge is constructed in the act of cognition, that it does not exist independent of the perceiving subject, that it is generated dynamically and not permanently stored, and thus cannot be simply »transmitted« to somebody else without idiosyncratic reconstruction [Papert (1992), 142]. Representations are constantly reinterpreted representational forms of the perceived, no static, fossilized symbols. That, however, also implies that there are always several possibilities of reconstruction. Consequently, the process of actively dealing with tasks becomes important: »This means that the learning of complex, unfamiliar or counterintuitive models in science requires a kind of learning by doing and by construction and criticism rather than by listening alone«

[Clement (1989), 377]. It is not defining of learning objectives and catalogues of cognitive concepts that is important, but making sure that the subject matter is perceived in its respective context.

These characterizations put constructivism close to an epistemological subjectivism, a potential point of criticism against which Glasersfeld (1995), to be on the safe side, defends himself at the very beginning of his book: »Some critics say that the emphasis on subjectivity is tantamount to solipsism […] others claim that the constructivist approach is absurd, because it disregards the role of society […] Both objections are unwarranted« (1). Such criticism misjudges the circularity of the cognitive situation, whose description is one of Maturana's and Varela's (1987) primary aims. Since we can neither simply presuppose an objective, independent world in cognition, nor want to fall into a subjective realism, they conclude: »We must walk a tightrope and avoid falling into either of the extremes – the representationist (objectivism) or the solipsist (idealism)«. Lakoff and Johnson (1980) also comment on this accusation and call objectivism and subjectivism myths which must be examined and understood, with the myth of objectivism occupying a special position: »The myth of objectivism is particularly insidious in this way. Not only does it purport not to be a myth, but it makes both myths and metaphors object of belittlement and scorn« (186).

Constructivism and Piaget

The foundations of constructivism can be found in Piaget on the one hand[4]. The theory of knowledge in Piaget's genetic epistemology emphasizes the genesis of cognition in the perceiving subject's active analysis of its environment. Pedagogic concepts of constructivism, such as the image of the »child as scientist«, go back to the principle found throughout in Piaget of the child acquiring knowledge through his own constructive activity in active examination of his environment [Brown/Palincsar (1989), 396ff.]. Brown and Palincsar are two of the few American scientists who do not misunderstand Piaget as a one-sided cognitivist, and who emphasize the common roots of Piaget and Vygotsky, which lie in the social genesis of individual understanding: »In fact, Vygotsky and Piaget, who are usually blamed for the extremes, acknowledged both social and individual learning in their theories, although each chose to focus primarily on one« (396).

Constructivism and Hermeneutics

The foundations of constructivism, especially the epistemological foundations, can on the other hand also be found in hermeneutics and symbolic interactionism, e.g. in Mead. French structuralism and symbolic interactionism already shared the view that knowledge does not consist of a set of abstract structures

4. Entwistle/Entwistle et al (1993); s. also Prenzel/Mandl (1993), 316, who also discuss the meaning of context as »contextualized knowledge« (318) in greater detail; s.a. Resnick/Klopfer (1989), 3. Almost all of the contributions in the volume of Forman and Pufall (1988) also exhibit this reverting to Piaget. diSibio (1982) tries to develop a constructive theory of memory by going back to Bartlett (1932) and Piaget and Inhelder (1973).

stored internally, but of current constructions. The accusation of objectivism, brought forward against psychological cognitivists and instructionalists by constructivists, goes back as far as the epistemological discussion about analytic philosophy. Habermas (1968) has pointed out that the conditions of instrumental and communicative action are also the conditions of potential cognition: »they define the meaning of the validity of nomological or hermeneutic statements. The embedding of cognitive processes in 'Lebenszusammenhängen'[life contexts] alerts us to the role of cognition-guiding interests: a life context is a context of interests« (260). The expansion of cognitive theory to social criticism throws open wide dimensions. In this view, objectivism becomes an expression of the social constitutionality of knowledge, which is the concern of the sociology of knowledge: »Objectivism has been firmly embedded in the norms and rituals of academic culture and its transmission« [Esland (1971)]. One of the few constructivist approaches in information science which consciously includes hermeneutic tradition (in this case, Gadamer and Heidegger) in its theory development is the approach of Winograd and Flores (1987) in their well-known book »Understanding Computers and Cognition«.

These determinations of the cognitive process are constitutive for the learning process. Learning develops from acting, acting occurs in social situations, thought and cognition are therefore situational. Or, to put it with the clear-cut sentences of Maturana and Varela: »All action is cognition, and all cognition is action«. With regard to the learning process, this means that attention must be directed towards cognition occurring in situ, being contextualized, or »situated«. For Forman and Pufall (1988), epistemic conflict, self-reflection, and self-regulation are therefore among the essential features of a constructivist theory of cognition. The graphic expression »situated knowledge« [Resnick (1989)], or »situated cognition« [Greeno (1988); Brown/Collins et al (1989)] and »situated learning« [Young (1993)] respectively, has been adopted for this idea. The most recent concept of »knowledge negotiation« might be suited to expanding the concept of situated cognition by a communicative dimension, if the authors [Moyse/Elsom-Cook (1992)] had not given the concept a rationalistically restricted form.

What Does Situated Cognition Mean?

Stucky (1992) states that the term 'situated' turns up in so many, completely incompatible contexts, that it had even led to dissension »in the situated ranks«: »But to some, all this looks like old hat. The claim made by the situated crowd often seems merely to be that interpretation, whether of language or action, depends on context. And that claim is, in many intellectual circles, hardly a new one« (27). It is therefore necessary and important to explain the concept of situated cognition more closely, in order to be able to distinguish premature citations of the concept from the few genuine constructivist approaches on the one hand, and avoid a too rash dismissal of the concept on the other. Let us turn to some explanatory attempts by the proponents of situated cognition.

Stucky, who criticizes lax use of the term situated cognition, tries the following explanation for herself: »It's not just that agents (whether human or computational) depend on the surrounding context in a variety of ways […] but rather that people rely on the context to do part of the work. They actively use aspects of the surrounding situation to calculate and support action in ways that suggest that they are not representing all relevant aspects of the situation at hand« (28). Cognition does not only occur within a context, but uses elements of that context. In this point, Stucky agrees with Lave (1988). For Lave, cognition is a social phenomenon: »The point is not so much that arrangements of knowledge in the head correspond in a complicated way to the social world outside the head, but that they are socially organised in such a fashion as to be invisible. Cognition observed in everyday practice is distributed – stretched over, not divided among – mind, body activity and culturally organised settings (which include other actors)« (1).

A somewhat simpler explanation of situated cognition is already familiar to every linguist and language philosopher: a speaker does not represent in his utterances everything that is necessary for cognitive and linguistic understanding. The meaning of the sum of references for I, he, she, here, there, etc., can grow out of a general context or a very private relationship, and may be understood only in the respective situation and by only certain conversation partners. If such utterances were machine translated, the context would be eliminated, and any meaning would necessarily be lost. Only the partner who inhabits the same context or has the necessary relation to the speaker can »understand« these utterances, and even he or she must produce considerable acts of interpretation. This simple example already makes clear: language and cognition are »situated in context«. The reference to machine translation suggests at the same time that the solution instructionalists might think of, simply to integrate more context into programs in order to ensure understanding, would be doomed.

»Situated Cognition« grew out of psychology's debate with Maturana [Knuth/Cunningham (1993)]. Maturana and Varela (1987) claim that human beings are structurally determined, autopoetic creatures, who are organized autonomously and recursively, but who react to perturbations of the environment by constructing idiosyncratic concepts. One of their most important statements is: »All knowledge is constructed«. Beings are closed systems with regard to information according to Maturana and Varela, i.e. they do not pick up information like objective givens, but only according to their own rules of interpretation. For constructivists, this is important evidence of the validity of multiple perspectives in cognition and learning. Beings are at the same time not independent of their environment, but structurally coupled to it, they conduct their interchange with the environment by way of symbolic action. Maturana and Varela are in agreement with Piaget here, whose main theme is the genesis of cognition from action, and with those epistemological theoreticians whose interest is directed towards the function of communicative action (e.g. Habermas). For Maturana, cognition is effective action, and any action is cognition.

For Knuth and Cunningham, the consequence of such an approach is that not the individual must be changed, but the environment within which the individual acts. The principles they deduce from Maturana's theory for the design of learning environments, are, in shortened form: »social coupling through language« and »network of conversation and dialogue«. Stebler, Reusser et al (1994) think that 'situated cognition' has its roots in the contextuality of thought, »which Duncker (1974) pointed out with his term of 'functional coupling« (230). If the individual's social coupling occurs through symbolic interaction, then situated cognition must necessarily deal with what the hermeneutic tradition calls »understanding«. One may well give up and retire from the tiresome business of definition when Stebler et al formulate: »Understanding is a multilayered and multifaceted phenomenon, for which we lack a reliable definition as yet«. As such facets, they list the following: »According to the respective theoretical approach, understanding means, for example, insight into factual correlations (Wertheimer, 1945/1964), productive reasoning (Duncker, 1974), integration of interrelated matter (Dewey, 1910, 1951), operational flexibility (Aebli, 1951), assimilation of new matter to existing structures (Piaget, 1947/1976), concept formation (Aebli, 1980, 1981), or problem-solving (Reusser, 1984)« (228).

Understanding and Hermeneutics

Surprisingly, the proponents of the situated cognition thesis have not dealt with the problem of understanding in the hermeneutic tradition. Nevertheless, I want to try to establish a connection here. Situated cognition is a counter concept against the functional misconception of cognition. Understanding has a phylogenetic and an ontogenetic side: as the understanding subject, I am part of a history of mankind (phylogenetic), and my cognition is moulded and obstructed by my belonging to that history. At the same time, I am a developing individual, and depend on a constant expansion and development of my incomplete cognition (ontogenetic). I understand differently as a five-year-old than I would as a twelve-year-old or twenty-year-old. Understanding means, therefore, to include history in reasoning in order to make up for this moulding: »In accordance with this theoretical discussion, an effective reception of information occurs in active analysis of a learning object (active) in a certain context (situated), together with others (interactive). In the course of this process, new information is coupled with already existing information (cumulative) and structures are built (constructive). Learning is most effective when the student knows the goal toward which he or she is working (target-oriented), and can competently monitor and direct his or her progress (self-regulated)« [Stebler/Reusser et al (1994), 231].

Constructivism and Learning Environments

The pedagogic consequences of this basic determination of the cognition process by the constructivists must consequently be aimed at respecting and paying more attention to the individual's autonomy and its idiosyncratic processes. This is not possible if the instruction predetermines objective knowledge and standardized methods, but only through the development of learning environments in which cognitive learning processes can occur in active interaction with that environment. Some interesting didactic concepts of and for learning environments have grown out of constructivism, such as

- the idea of »cognitive apprenticeship«, which has been made familiar by Collins, Brown et al (1989) [s.a. Brown/Collins et al (1991)],
- the »communities of practice« of Brown, Collins et al (1989) or
- the »reciprocal teaching« of Brown and Campione (1990),
- the »intentional learning« of Bereiter and Scardamalia (1989), and Scardamalia und Bereiter (1992),
- the »knowledge-building communities«, Scardamalia und Bereiter (1992), as well as finally
- the all-embracing concept of »legitimate peripheral participation« of Lave and Wenger (1991).

The idea of situated cognition has brought about a sort of renaissance of social learning, a new edition of contextual, cooperative and communicative learning situations. One of the teacher's main task, therefore, is to find situations which stimulate learning and allow the development of new concepts and procedures. Whether one should emphasize situations of successful learning, as Pea (1992) suggests (314), and especially those situations which arise beyond the school environment, or whether on the contrary one should concentrate on situations of unsuccessful learning, I will leave open. In any case, the focus in constructivism is suddenly on completely different aspects of learning than during the last 20 years:

- everyday knowledge of learners
- preferred learning strategies of learners
- the individual's individual state of knowledge
- a generic theory of knowledge acquisition
- acquisition of new and modification of already acquired cognitive concepts, change of concepts
- the knowledge-building power of learning communities
- situations of vocational training and practice.

With regard to the development of learning programs, two consequences of the constructivist approach are particularly remarkable:

- the emphasis on alternative learning situations or learning environments

- the development of alternative design processes.

Emphasizing Alternative Learning Environments

Brown (1985) makes clear that constructivist education also demand new learning situations in the area of computerized learning. He wants to shift the focus of interest from learning results to learning processes. Five means seem important to him: (1) »empowering learning environments«, in order to stimulate creativity, (2) »games«, in order to address motivation, (3) cognitive tools, in order to foster representation and the understanding of cognitive processes, (4) tools for fostering writing and arguments, and (5) programs which mirror the students' reasoning and support them in reflecting their own thought processes. Papert has designed very similar concepts, from the first experiments with microworlds in Turtletalk in Logo, by way of computer-supported Lego machines, up to comprehensive school projects like »Project Headlight« [Harel/Papert 1991a]. Papert also sees the development of creative and stimulating learning environments at the forefront of his pedagogical efforts [Harel/Papert 1991b]. But there are differences nonetheless. Papert emphasizes them by choosing the term »constructionism« instead of constructivism. What matters most to him are learning situations that allow active constructing, although all his descriptions of pedagogic reality show how much he,too, sees the learning process as situated within the context of a social environment.

The Concept of Learning Environments

The concept of learning environments clearly demonstrates the leap from traditional theories of learning or the taxonomies of Gagné or Merrill to constructivism: Brown does not so much ask for new models of instruction or further prescriptions and presentation forms, as for alternative learning environments. The term »learning environment« gains currency [Duffy/Lowyck et al (1993)]. Thinking about learning environments brings about a renaissance of the methods of problem-solving and discovery learning. A much-cited example in this context is the Jasper Series of the Cognition and Technology Group at Vanderbilt [CTGV (1992) and CTGV (1993)], although these are not concerned with computer programs, but video films [s.a. Spiro/Feltovich et al (1991b); Cooper (1993)].

Education and teaching cannot assume, in a constructivist perspective, that all learners simply absorb the aims of instruction unchanged, they are rather defined by the maxim that learning individuals are autonomous subjects who react to the perception of perturbations in their environment by generating idiosyncratic concepts. What must be kept in mind here is that constructivism does not reject the planning of instruction, but sees as its most noble task the invention and design of stimulating learning environments which offer learners the freedom to create their own constructions. It is still a design task, albeit a different one than in instructional design: »The ideas underlying constructivism suggest that we shift from designing learning environments that instruct to designing environments that influence the structure of autopoetic unities in ways that conserve organization and adaptation« [Knuth/Cunningham (1993), 167].

diSessa (1992) calls the descriptions of alternative learning environments and learning concepts in constructivism, such as the phrase »child as scientist« or »child as designer/builder« (Papert, Minsky), »images« (19ff.), which pretty accurately circumscribes their methodological status: As of now, these are only metaphors for learning, images that have a guiding nature, but no theories of learning as yet. diSessa also coins the term »activity« for this, and would like to break through to a theory of activity.

Jasper Series

The Cognition and Technology Group at Vanderbilt, which has developed a well-known series of video films, the Jasper Series, utilizes hypertext terminology in order to describe their theory: Their films offer semantically rich »anchors«, which construct a »macrocontext«. These macrocontexts present meaningful authentic problems which must be solved. What is important to them is the activity of learning itself (generative learning), embedded communication and cooperation (16), and the meaningful problem-solving context (anchored instruction) which contains elements of »apprenticeship learning« (17) and allows explorative action.

Taliesin Project

Smith and Westhoff (1992) describe the Taliesin Project, whose aims go far beyond a program and touch on the institutional context: (1) curriculum revision with the aim of overcoming the segmentation of subjects and introducing interdisciplinary block teaching, (2) development of a hypermedia system with protocolling, communication, network connection, application, (3) development of tools for designing lessons.

An important feature of these learning environments is that they are social learning environments, in which human beings communicate by way of symbolic sign systems. From this concept, three approaches for the differentiation of learning environments and for their construction have developed:

- learning as apprenticeship (cognitive apprenticeship)
- learning as communicative action in knowledge communities
- learning with cognitive tools.

Cognitive Apprenticeship

The concept of »cognitive apprenticeship« [Collins/Brown et al (1989); Brown/Collins et al (1991)] puts the emphasis on learning that is embedded in a social context in which master and apprentice both have a part: »apprenticeship embeds the learning of skills and knowledge in their social and functional context« (454). Elements of apprenticeship which the authors have in mind are the observation of the master by the apprentice with the aim of building up a model (modelling), the apprentice's independent practising with advice from the master (coaching), and the gradual lessening of tutorial activity (fading). Stebler and Reusser et al (1994) choose the German term »Berufslehre« (vocational training) for cognitive apprenticeship, which probably does not quite hit the right meaning if we think of all those descriptions of cognitive apprenticeship which Lave and Wenger (1991) have gathered from ethnographic studies in Africa.

The processes which are put into practical action in actual apprenticeship take place in the minds of the participants in this case, i.e. they are cognitive. An important element here is the externalization of cognitive processes [Lajoie/ Lesgold (1992)]. And so we have come back full circle to the hypothesis of situated cognition. Many advantages are ascribed to cognitive apprenticeship: observation and independent practical realization (externalization) of certain skills are said to foster the development of the cognitive model; the cognitive model provides an interpretative structure, so that feedback, advice and corrections fall on fertile ground, through which in turn the autonomous skill of reflection is supposed to develop.

Even a cursory description of the concepts shows: constructivist learning goes far beyond that which computers can do or understand [Nix (1990)]. His examples, in which children edit videos with the help of computers and write modern narrative stories, provide evidence for this hypothesis: »The computer is decentered enabling technology for experiences whose significance transcends computeristic ideas. The children work together. What they work on is relevant to their own feelings and thoughts. Their work consists of creating something. The computer could not know what they were doing« (160).

Knowledge Communities

Cooperative learning, interactive learning and learning communities receive new attention from constructivism [Newman (1992)]. This is bound up with the idea of a »distributed cognition«, for which constructivists cite Vygotsky. Brown and Palincsar (1989) give an overview over anthropological, cultural and social roots of cognition development in cooperative settings, over »shared expertise«, »expert scaffolding«, the role of conflicts, the function of Socratic dialogues, the concept of reciprocal teaching of understanding, incidental learning etc. (397ff.). I cannot go into all of these in detail, but I would like to illustrate the idea by way of one example.

CSILE Scardamalia and Bereiter (1992) describe CSILE (Computer Supported Intentional Learning Environment), a family of general developing tools, networked hypermedia programs which are not restricted to one knowledge domain, but are meant to be employed throughout the curriculum, and whose aim is the cooperative construction of knowledge by the student in and out of the class room. The theoretical basis of CSILE is the concept of intentional learning [Bereiter/Scardamalia (1989)], an attempt to have students learn intentionally with certain aims in view. CSILE offers an interactive environment for this, which includes a so-called »community database« and several »knowledge-building environments«: Home, Explanation, How-it-Works, Data Exploration, Meanings, Expert, Documents. With these tools, the students can form a knowledge-building community, in which they themselves take responsibility for their learning. The concept has many points of contact with other pedagogical concepts like discovery learning, problem-oriented learning or project-oriented learning.

Among the design principles of CSILE are:

Objectification	Knowledge is treated as an object which can be criticized, modified, compared and set in relation to other things
Progress	Knowledge constructions must lead to a goal, and any progress must be made clear to the student
Synthesis	Support of representations of a higher order
Consequences	Action must result in consequences, such as feedback
Contribution	Every student's individual contribution must be seen as a contribution to the community database
Fertilization	Users come into contact with other areas, topics, ideas
Socialization	The social aspects of school are to be integrated into the system as well.

Bereiter and Scardamalia describe two different methods of using CSILE, as »independent research model« on the one hand, and as »collaborative knowledge-building model« on the other. In the former case, the software is used for individual learning. The individualized use of CSILE is not without profit: students write a lot, utilize diverse sources and learn many new terms. In the latter case, the learners plan their learning as a group, work cooperatively, and comment each other. The authors conclude that the second model uses the new media's potential for knowledge-building more effectively (229). In a comparative evaluation they reach the conclusion that the cooperative model has proved superior to the individualized model: »These results suggest that a Collaborative Knowledge-Building model of communal database use does indeed foster more exploratory and collaborative uses of the database, leading to a higher quality of knowledge development« (240).

A similar model is Allen's (1992) »MultiMedia Works Club«. He proposes a concept that clearly has its roots in anthropology, his emphasis lies on the construction of an environment, not on specific, teacher-planned or domain-specific learning processes. No formal evaluation has been carried out as yet, but there are reports of many indicators for participation, enthusiasm, and successful production.

Communication in Networks

The emphasis which constructivism puts on learning situations and learning environments fits in with the growing role of communication in networks: »Computers and computer networks provide a beautiful opportunity for subcultures to form and grow independent of geography but dependent on shared beliefs, interests, etc.« [Brown (1985), 183]. Brown therefore calls the computer a »communication facilitator« (184). Campione, Brown et al (1992) describe an experiment with networks and hypertext software in three schools: Clear progress in reading and writing and an increase of knowledge can be established. They see the embedding of technology into the normal learning environment and the possibility of cooperation through the network as decisive factors for success. Brown and Campione (1990) experiment with the method of reciprocal teaching and learning, i.e. all students take over the teacher role in turn. The subject of Brown's and Campione's experiments is text understanding, i.e. a hermeneutic area of knowledge which does not come into focus with most systems in instructional design or intelligent tutoring systems. A completely different line is taken in the »Lab Design Project« and other projects of Honebein, Duffy et al (1993): they mostly serve an immersion into the role of researcher, the development of »research skills«. Similar experiments with networks are STF (*Strategic Teaching Framework*) and the *Hypermedia Library* of the Indiana University, Ill. [Jones/Knuth et al (1993)]. Levin, Reil et al (1985) report on projects they have carried out in networks with students of several countries. They hope that the wealth of information will also clarify the differences in the ways in which individuals interpret facts. Promoting pluralistic perspectives and making the collaborative nature of knowledge more transparent are two of the reasons why constructivists are interested in communication in networks [Wolf (1988)].

Communication and Meaning

Contextual learning and learning in knowledge-building communities always presuppose communication. One of the few constructivists who pay special attention to communication is Pea (1992). He puts special emphasis on the aspect of learning through conversation and language games in discourse, in conjunction with cognitive learning processes in problem-solving. Pea embeds the physical simulation program *Optics Dynagrams Project* into classroom conversation. Other forms of activity emphasizing cooperation and communication are added deliberately. Pea calls this »augmenting the learning conversations«. The students construct interactive physical »scenes« with the help of the 2D optics program, which are then computed in the simulator. The result, displayed in form of a diagram, provides the stimulus for discussion in small groups with the teacher as tutor. Peas overall system probably exhibits the most comprehensive compendium of constructivist ideas of learning that I have ever met: »authentic activity from a community of practice, in-situ role modelling of appropriate activity for a practitioner in the community of practice, and learners' legitimate peripheral participation in that community; opportunities for use of concepts and skills that allow for social meaning repair and negotiation; and the keystone activity of collaborative sense-making through narration – to provide reasonable causal stories that account for some event with a set of explanatory constructs« (340).

It is surprising that only so few proponents of constructivism, all of whom emphasize the relevance of a »negotiation of meaning«, concern themselves with the actual act of the communicative negotiation of meaning. The concept of social knowledge-building communities comes in in just the right place, after all, namely the embedding of knowledge-building in communicative action. The consequences resulting for communication in constructivist learning environments from the concept of the construction of meaning in the act of cognition, from situated cognition and the contextuality of cognition processes, have hardly been interpreted with regard to communication theory until now. The role of communication and discourse in knowledge-building communities has unfortunately not yet been described. I say unfortunately, because a highly restricted use of the terms communication or discourse (as „discourse" between user and machine) has become common in information technology literature which forces a one-dimensional meaning on these terms.

Stebler, Reusser et al (1994), after giving an overview of constructivist experiments on learning in knowledge-building communities, formulate several hypotheses regarding interactive learning in learning environments. They claim that such concepts

- foster the integration of intuitive and formal knowledge
- foster process-oriented and goal-oriented learning
- foster knowledge-building in learning partnerships and communication communities
- create the prerequisites for transfer.

Cognitive Tools

I can skip the topic of cognitive tools here, because I will discuss it in more detail in a separate chapter (Chapter 10).

Emphasizing Alternative Design Processes

An essential distinction from traditional software development in constructivism consists in the fact that it is not sufficient to design the practical use of learning programs, their pedagogical employment, in the laboratory, but that one has to use alternative strategies even in design [Clancey (1993)]. It is not enough to simply envision the eventual users in designing the program, to model them and their environment along with the software, in the assumption that such design will lead to predictable effects. It proves necessary, on the contrary, to incorporate the community of learners into the design process. In agreement with socio-technical theories Clancey speaks of »participatory design«. Gayeski (1992) also sees participatory design as the solution, out of the experience that programs which are developed within companies are more successful than those bought externally. Clancey's reason for choosing this route was the experience that the programs he had developed earlier were actually not being used: »After more than a decade, I felt that I could no longer continue saying that I was developing instructional programs for medicine because not a single program I worked on was in routine use (not even Mycin)« (7).

What emerges as a common denominator and effective concept is the concept of environment, which embraces relations between persons, cooperation and communication. The significance of these examples amounts to more than just their status within constructivism: »There seems good reason to believe that these lines of work represent early versions of what we will recognize a decade from now as a major new line of development in cognitive theory as a whole and in instructional theory in particular« [Resnick (1989), 11]. One critical question remains: Is this renaissance of learning environment, learning communities and situated cognition something permanent or just a fad? Today, such experiments seem new, pupils and students participate willingly. But what happens once the expedition into environments is a common experience from earliest childhood? Will the same learning difficulties resurface which occur in traditional school today? This question can also be asked of the current trends of networking and communication in networks [Pea/Gomez (1992)], which are seen increasingly positively now.

Pseudo Theories or Partial Theories of Learning

Apart from these main theories of learning, there are many concepts of smaller scope, which call themselves cognitive theories, or even theories of learning, and come from very different directions, stemming now from cognitive psychology and motivation psychology, now from information theory. I will follow the custom of American literature on information science here, which usually has one or two paragraphs of »name dropping« at the beginning of an article:

- Information-theoretical approaches I cannot, or only briefly, deal with in this book are e.g. the *Physical Symbol System Hypothesis* [Newell/Simon (1976)], schemata theory [Rumelhart/Norman (1978); Rumelhart (1980)], production systems [Anderson (1983)], PDP (Parallel Distributed Programming) and connectionism [McClelland/Rumelhart (1986)], discriminatory learning [Langley (1987)], ACT* (Adaptive Control of Thought) [Anderson (1983)], propositions and declarations [Kintsch/van Dijk (1978)], rules and procedures, SOAR [Laird/Rosenbloom et al (1986)], machine learning, learning by chunking [Rosenbloom/Newell (1987)], theory of mental models [Johnson-Laird (1983); Gentner/Stevens (1983)].

- Neither can I deal with the following psychological approaches: e.g. the theory of cognitive dissonance [Festinger (1968)], theory of cognitive conflict [Dreyfus/Jungwirth et al (1990)], theory of cognitive complexity [Schroder/Driver et al (1967); Mandl/Huber (1978)], theory of cognitive flexibility [Spiro/Coulson et al (1988)], dual-coding theory [Paivio (1978)], and NLP (neurolinguistic programming) [O'Connor/Seymour (1993)].
- Finally, there are a number of concepts regarding thought processes that I will not touch on, e.g. informal reasoning [Voss (1988)]; abductive reasoning [Ross/Shank (1993)]; non-linear reasoning, purple people [Tenny (1992)] and lateral reasoning [De Bono (1976)].

I do not want to (and do not have to) deal with these hypotheses within this book, because

- —like information-theoretical approaches—they do not add anything new to the topic of multimedia learning in my opinion, or refer to areas of learning, e.g. discrete systems or problems of artificial intelligence, which are only implicitly of interest here by way of the learning systems discussed (Instructional Design, Intelligent Tutoring Systems, Expert Systems) and will be briefly dealt with in that context,
- —like psychological approaches—explain a much too small area of the phenomenon. In the following, I will therefore only briefly deal with those psychological-cognitive theories which are often cited as foundation by the authors of literature on computer-supported learning.

»Cognitive science is overflowing with theories. There are theories of decay, encoding, retention, and retrieval; theories of analogy, composition, deduction, discrimination, generalization, and induction; theories of insight, planning, restructuring, and search; and so on. But there is more unity than this diversity suggests" [Ohlsson (1990), 563]. This list is biased, Ohlsson omits precisely those two genetic-epistemological theories of cognition which I have discussed in this chapter, Piaget and the constructivists. The rest of »Cognitive Science« is the »Standard Theory« of cognition to Ohlsson: »The Standard Theory is the first theory in the history of psychology to apply with formal precision to such a wide range of phenomena« (569). What Ohlsson means by a wide range of phenomena are examples from Rubik's cube to medical diagnosis – a somewhat one-sided selection from the cosmos of cognitive problems. Cognitive Science, and especially the *Physical Symbol System Hypothesis* [Newell/Simon (1976)], which Ohlsson cites as grounds for his position, and which strives for the reproduction of symbolic structures or symbol processing with the aim of simulating human thought processes and language production, will be discussed in more detail in the chapter on instructional design. The use of these models for the design of tutored or independent human learning is problematic, however. This problem will be repeatedly addressed in the following chapters under the heading of »correspondence hypothesis«. Connectionist approaches, which are impressively and usefully employed in areas of subsymbolic machine learning, and regognition of vision, handwriting and speech, will be treated in the chapter on hypertext systems. Connectionist models are hypotheses about the 'missing link' between the neuronal structures of the brain and memory and observable behaviour, with the aim of achieving functional models that eventually might be able to perform quasi-human achievements. This is both legitimate and sensible. But these theories prove problematic instruments in the hands of a researcher of teaching methods attempting to develop instruction, tutorial systems, and multimedia for human learning, because they turn into hypotheses on mechanisms of memory and human cognition when applied to real learning processes, and thus become a reification of mental processes.

The psychological hypotheses are strictly speaking no theories, let alone theories of learning, but isolated theorems or splinter hypotheses on learning. Psychological literature has witnessed an inflatory use of the term theory: any concept that can be partly systematized is presented to the scientific public as a theory, even if it only covers an isolated small aspect of the complex learning process. One could also designate these approaches as pseudo theories or partial theories. The authors of these pseudo theories ignore wide areas of learning phenomena, other methods of learning, and other conditions of learning environment, and base the proof of their theories on either test procedures or artificial learning situations. The results can therefore not be generally applied to learning environment, types of learners, subjects, and transfer of subjects learned. Reference to such pseudo or partial theories in the development of concrete learning environments would lead to a fragmentation of learning, as many examples citing these approaches prove.

Pseudo theories recognize elements of the learning process at best (learning strategies, teaching strategies, attitudes). The warning that Entwistle, Entwistle et al (1993) have pronounced with regard to cognition-psychological theories in general especially applies to such partial theories: »However, it is important not to locate implications for instructional design solely within this new generation of cognitive theory. It is essential to keep an appropriate historical perspective, which sees a continuing tradition from both philosophers and psychologists to avoid the narrow view of human learning espoused by another powerful tradition of theorists« (331ff.). Entwistle and Entwistle et al on their part refer to Kohler, whom they see as a representative of problem-solving, to Piaget, whom they see as the constructivists' antecedent, and to Bruner and Ausubel.

Dual-Coding Theory

The dual-coding theory [Paivio (1978)] postulates two independent cognitive coding mechanisms for the reception and processing of verbal and visual information. While language is generated and received sequentially (this partial hypothesis alone could be contested from a linguistic point of view, as sign language research has proved), visual information is accessible simultaneously according to Paivio (1978) [cf. Paivio (1983)]. According to Rieber and Kini (1991), animations serve to foster dual coding. The hypothesis of a separate cognitive processing of visual and verbal information has been disputed, but not the possibility that sequential (non-verbal) and spatial (non-visual) data are cognitively processed in different ways, as Clark and Craig (1992) assume. The dual coding theory is understandably cited by many multimedia designers as grounds for the integration of several media, and thus plays a part in many evaluation studies on interactive laser disc systems.

Theory of Cognitive Flexibility

The theory of cognitive flexibility [Spiro/Coulson et al (1988)] means the ability of spontaneously restructuring existing knowledge structures in response to changed situations and conditions, both within a certain area of knowledge and across knowledge domains. Spiro et al assume that there are areas of knowledge which are so complex that they cannot be grasped through simple rules, and which they call »ill-structured domains«.

Spiro and Jehng (1990) develop their concept of cognitive flexibility from Wittgenstein's metaphor of a criss-crossed landscape: »We use the metaphor to form the basis of a general theory of learning, instruction, and knowledge representation. One learns by criss-crossing conceptual landscapes; instruction involves the provision of learning materials that channel multidimensional landscape explorations under the active initiative of the learner (as well as providing expert guidance and commentary to help the learner to derive maximum benefit from his or her explorations); and knowledge representations reflect the criss-crossing that occurred during learning« (170). A new network-like semantic structure emerges. In order to foster cognitive flexibility, knowledge must be presented in diverse ways and in the form of complex schemata and scenarios.

Spiro and Jehng establish a close connection between their theory of flexibility and the hypertext concept, and illustrate this connection by way of a program with laser disc on the film *Citizen Kane*. Spiro, Feltovich et al (1991a), and Spiro, Feltovich et al (1991b) file their flexibility hypothesis under the heading of constructivism. The reaction of instructionalists, who basically oppose constructivism, but can just about accept this approach [Reigeluth (1991)], demonstrates that the theory of cognitive flexibility is not a truly constructivist approach [s.a. Schell/Hartman (1992); Jonassen (1992c)]. One may well ask whether such a pictorial description can be more than mere metaphor, and just how serviceable it can be. I will come back to its theory status and the methodologically questionable construct of »ill-structured domains« at a later point (chapter 7). It is certainly not a theory of learning.

Other partial theories of learning known from pedagogics are the differentiation of deductive vs. inductive learning, or that of incidental vs. intentional learning [Bock/Kirberg et al (1992); Strittmatter/Dörr et al (1988)]. Discussions about exemplary learning, »explanation-based generalization«, or »case-based learning« show into what kind of difficulties such distinctions lead. The differentiations are interesting from a heuristic point of view and helpful as global designations for global teaching approaches, but they are not precise enough in learning situations, because deductive and inductive, incidental and intentional processes always occur in mixed form in real learning processes. Clark (1992) uses the differentiation of deductive vs. inductive learning as a criterion for typing transfer teaching methods.

Some of these theories (cognitive flexibility theory, information processing theory, case based reasoning, generative learning, semantic networks, dual coding theory) and their relation to the hypermedia concept are discussed in Borsook and Higgenbotham-Wheat (1992). Jacobson and Spiro (1994) attempt to compile these theories in a »Contextual Analysis Framework« for technological learning environments. Goodyear, Njoo et al (1991) try to construct a general framework for approaches in theory of learning, with a special view to simulation or cognitive learning processes in explorative learning environments. Both these attempts try to create a general framework, within which the different theories can be appointed a certain rank. Whether such an undertaking makes sense methodologically speaking would have to be settled metatheoretically first. An interesting attempt at a metatheoretical discussion of these theories of learning is a presentation of theories of learning in hypertext form [Kearsley (1993)]. His TIP database (Theory Into Practice) of 45 theories of learning, 18 concepts and 17 knowledge domains, created with *HyperTIES*, demonstrates a relatively low extent of internal links between the theories, concepts and domains. This contradicts Snelbecker's (1983) hope that a synthesis of theories of instruction will be possible.

It seems that new approaches do not like to refer to older ones, so that no historical development can come about. Many pseudo theories only deal with some very special phenomenon. Such a departmentalization of theory does not serve any useful scientific function, but probably has a social motivation: these are fairly obvious tendencies of hunting out niches for the foundation of scientific schools.

Prospect of Further Chapters

There is one theory of learning I have not addressed in this chapter, behaviourism. I will make up for that in the very next chapter, which deals with the history of authoring systems and their transformation into modern courseware. Today, modern authoring systems and courseware have become developing environments for multimedia as well. In the further chapters of this book, I will deal with the development of the theory of instruction and instructional design, intelligent tutoring systems, and hypertext systems. The following timetable gives an overview of the main proponents and scientific milestones of the movements that have contributed to the foundations of multimedia:

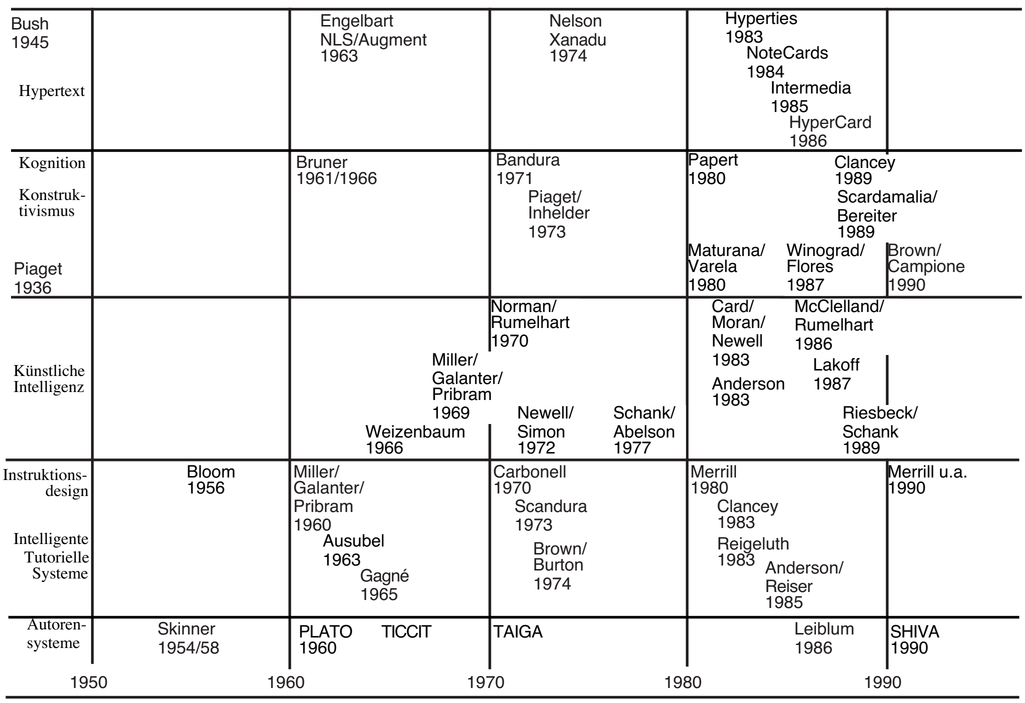


FIG. 5
Timetable of
scientific schools

After the three great movements authoring systems, instructional design, intelligent tutoring systems, and hypertext, I will go into a number of forms of multimedia which are close to practice: electronic books, presentations and KIOSK system, interactive learning programs, cognitive tools, modelling programs, and simulations. Finally, one chapter will deal with the evaluation of all these systems and applications at length, although the chapters on the individual types of learning systems will all have a subchapter in which results of evaluations of these systems are reported.

CHAPTER 4

CAL, CAI, ICAI, CAT, CBT, CBI, PI, or what?

Authoring Systems and Courseware

Authoring systems have their past history in Programmed Instruction[5]. The first programs in Programmed Instruction tried to translate Skinner's (1958) theory on operant conditioning into learning programs. Behaviourism in its initial variant (the »classical conditioning« of Pavlov) started from the assumption that certain stimuli (S) provoked certain responses (R), and that such S-R-couplings are strung together into chains (paired associations) and can be habitualized in this form, especially if desired (correct) responses are followed by appropriate rewards, while undesired responses remain unrewarded and are therefore deleted. Skinner (1954), in contrast to the basic behaviourist model, assumes that behaviour is not simply responsive, but can also occur spontaneously. He calls such behaviour »operant«. The probability of the occurring of operant behaviour can be conditioned through suitable »reinforcement«. Skinner's behaviourism constructed learning on the principle of intermittent reinforcement. The learning matter was broken down into very small units, so-called »frames«. After each unit, an answer was required from the learner, which was then compared with the correct or desired answer:

A Set of Frames to Teach the Spelling of 'manufacture' to Third-Graders [Skinner 1958]

1. Manufacture means to make or build. Chair factories manufacture chairs. Copy the word here:

   __ __ __ __ __ __ __ __ __ __ __

2. Part of the word is like part of the word factory. Both parts come from an old word meaning make or build.

   m a n u __ __ __ __ u r e

3. Part of the word is like part of the word manual. Both parts come from an old word for hand. Many things used to be made by hand.

---

5. On the history of the early learning machines before Programmed Instruction, s. Niemiec/Walberg (1989) and Lumsdaine/Glaser (1960), the latter with illustrations of early learning machines and an annotated bibliography of the literature before 1960, and Glaser (1965); on the roots of behaviourism in learning theory s. McKeachie (1967); Fraser (1989); Kulik/Kulik (1989); Baumgartner/Payr (1994) 100ff.

__ __ __ __ f a c t u r e

4. The same letter goes in both spaces:

   m __ n u f __ c t u r e

5. The same letter goes in both spaces:

   m a n __ f a c t __ r e

6. Chair facturies __ __ __ __ __ __ __ __ __ __ __ chairs.

Correct answers were followed by reinforcement. Mistakes had to be avoided, because negative feedback was undesirable. Therefore even the smallest steps of learning were often accompanied by help and strongly suggestive, as the following example shows:

Excerpt from a Machine Physics Program for Pupils [Skinner 1958]

Sentence to be completed	**Word to be supplied**
1. The important parts of a flashlight are the battery and the bulb. When we “turn on” a flashlight, we close a switch which connects the battery with the _______ .	bulb
2. When we turn on a flashlight, an electric current flows through the fine wire in the _______ and causes it to grow hot.	bulb
3. When the hot wire glows brightly, we say that it gives off or sends out heat and ________ .	light
4. The fine wire in the bulb is called filament. The bulb “lights up” when the filament is heated by the passage of a(n) ________ current.	electric
5. When a weak battery produces little current, the fine wire, or __________ , does not get very hot.	filament
6. A filament which is less hot sends out or gives off _____ light.	less
7. “Emit” means “send out” The amount of light sent out or “emitted,” by a filament depends on how _____ the filament is.	hot
8. The higher the temperature of the filament the _________ the light emitted by it.	brighter
9. If a flashlight battery is weak, the __________ in the bulb may still glow, but with only a dull red color.	filament
10. The light from a very hot filament is colored yellow or white. The light from a filament which is not very hot is colored _____ .	red
11. A blacksmith or other metal worker sometimes makes sure that a bar of iron is heated to a "cherry red" before hammering it into shape. He uses the ________ of light emitted by the bar to tell how hot it is.	color
12. Both the color and the amount of light depend on the _________ of the emitting filament or bar.	temperature
13. An object which emits light because it is hot is called “incandescent.” A flashlight is an incandescent source of ______ .	light

14. A neon tube emits light but remains cool. It is, therefore, not an incandescent _______ of light. — source

15. A candle flame is hot. It is a(n) __________ source of light. — incandescent

16. The hot wick of a candle gives off small pieces or particles of carbon which burn in the flame. Before or while burning, the hot particles send out, or ______ , light. — emit

17. A long candlewick produces a flame in which oxygen does not reach all the carbon particles. Without oxygen the particles cannot burn. Particles which do not burn rise above the flame as ______ . — smoke

18. We can show that there are particles of carbon in a candle flame, even when it is not smoking, by holding a piece of metal in the flame. The metal cools some of the particles before they burn, and the unburned carbon _________ collect on the metal as soot. — particles

19. The particles of carbon in soot or smoke no longer emit light because they are ________ then when they were in the flame. — cooler, colder

20. The reddish part of a candle flame has the same color as the filament in a flashlight with a weak battery. We might guess that the yellow or white parts of a candle flame are ________ than the reddish part. — hotter

21. “Putting out” an incandescent electric light means turning off the current so that the filament grows too _______ to emit light. — cold, cool

22. Setting fire to the wick of an oil lamp is called __________ the lamp. — lighting

23. The sun is our principal _________ of light, as well as of heat. — source

24. The sun is not only very bright but very hot. It is a powerful ___________ source of light. — incandescent

25. Light is a form of energy. In "emitting light" an object changes or “converts,” one form of _________ into another. — energy

26. The electrical energy supplied by the battery in a flashlight is converted to ________ and ________ . — light, heat

27. If we leave a flashlight on, all the energy stored in the battery will finally be changed or ____________ into heat and light. — converted

28. The light from a candle flame comes from the _________ released by chemical changes as the candle burns. — energy

29. A nearly “dead” battery may make a flashlight bulb warm to the touch, but the filament may still not be hot enough to emit light—in other words, the filament will not be ___________ at that temperature. — incandescent

30. Objects, such as a filament, carbon particles, or iron bars, become incandescent when heated to about 800 degrees Celsius. At that temperature they begin to ____ _______ . — emit light

31. When raised to any temperature above 800 degrees Celsius, an object such as an iron bar will emit light. Although the bar may melt

or vaporize, its particles will be ____________ no matter how hot they get. incandescent

32. About 800 degrees Celsius is the lower limit of the temperature at which particles emit light. There is no upper limit of the ___________ at which emission of light occurs. temperature

Skinner claimed that learning programs constructed in this way could dispense reinforcement much better than human beings, and were therefore better than exercise books and could even replace teachers. A great amount of reinforcement was necessary, however, about 25.000 for learning simple arithmetic [Skinner (1958), 204]. Similar claims are still repeated almost 30 years later by Gropper (1983). Authoring systems was the name given to programs which were meant to make it easier for authors to »write« learning programs of this kind. How little the authoring systems themselves followed this model, which they merely laid claim to in metaphorical manner, and how wrong it is to analogize feedback and reinforcement, has been demonstrated in detail by Fischer [(1985), 69ff].

From this model of the behaviour and learning process, Skinner developed a model of teaching and learning behaviour which seemed to find wide dissemination under the name of »Programmed Instruction« in the sixties and early seventies, but then quickly disappeared from view. The US Army was very interested in drill & practice programs, and supported Skinner's rise [Niemiec/Walberg (1989)]. For certain training purposes, the principle of drill & practice can still be usefully applied, and thus research is still being done on this topic [e.g. Vazquez-Abad/LaFleur (1990)]. The approach of discriminating »skills« which can be learned, and to subdivide them into »subskills«, of which some can be trained by drill, makes use of this technique as well [e.g. Salisbury (1990)].

Linear and Branching Programs

The beginnings of authoring systems were linear programs which doggedly presented one prefabricated exercise after the other, »simple electronic text presentations or exercise programs which put a question, marked the learner's response as 'right' or 'wrong', and then went on to the next question« [Mandl/Hron (1990), 18; Lesgold (1988)]. Because they demanded a response from the learner, Jonassen (1985) already calls them interactive programs. Rejection of these linear programs' rigidity, coupled with the intention to drive forward the individualization of Programmed Instruction, led to the development of programs which could branch into subprograms when required [Niemiec/Walberg (1989)], a first step in the direction adaptive systems, as Jonassen (1985) thinks. But branching programs could not gain ground either according to some authors, for one thing because it became impossible for the authors to control the combinatorial explosion of branches in a practicable way, but most of all because the program branches did not basically change the behaviourist character of Programmed Instruction, »the dominant paradigm that restricted research to external, observable learning behaviour, without taking into account the internal representation of knowledge […]« [Mandl/Hron (1990)].

Authoring Systems

By adding simple programming languages and the possibility of branching, authoring systems came into being[6]. Authoring systems initially merely tried to imitate the working methods of Programmed Instruction's learning machines of the fifties and sixties, i.e. those page turning machines which presented texts on a kind of microfiche screen and put questions with regard to these texts which the learners could answer by way of a special keyboard with a small number of keys. The authoring systems followed this pattern. Streitz (1985) laments the simple transfer of sixties' models to the authoring systems of the eighties: »One would wish for a much more user-friendly design here, which would allow for flexibility and the realization of creative ideas in the design of computer aided instruction « (57). The learning objectives of these programs lay mostly in the domain of fact and knowledge mediation. They presented the learner with short texts and multiple choice questions (questions with given wrong and correct answers).

Generative Programs

We can distinguish between authoring systems which simply play prefabricated frames as in Programmed Instruction and those authoring systems which generate tasks ad hoc, so-called generative programs [O'Shea/Self (1983)], and which can better react to the learner's situation in this way. Modern authoring systems have partly detached themselves from the initial type's strict scheme and allow a somewhat freer treatment of the learning material presented, i.e. they do not always have to close a lesson with questioning the learner and a logical test of his answers. The term »courseware« has been found for these more open systems.

PLATO and TICCIT

The two authoring systems which were installed in larger clusters in the USA, and which were both initiated or supported by the National Science Foundation of America, were PLATO (programming language Tutor, distributor: Control Data Corporation) and TICCIT (Time-shared Interactive Computer Controlled Instructional Television; programming language ADAPT; distributor: Mitre Corporation). TICCIT was installed by the National Science Foundation

6. An early historical retrospective of the development of CAI and the studies on CAI mostly in the USA and England is provided in Chambers and Sprecher (1980). The report also comments on the prognoses for the nineties. It ends in a number of recommendations, of which the first is a demand for a »nationwide, standard high-level CAI language« (340). Later reports can be found in Park, Perez et al (1987), and Niemiec and Walberg (1989).In their overview of authoring tools, McDermott Hannafin and Mitzel (1990) point out the universities in the USA at which such systems were installed on a large scale. On the criteria by which authoring systems may be distinguished, s. Hunka (1989). Schamda (1989) compares 12 authoring systems: Aristoteles, EasyTeach, Etas, Maccao, Mavis, Miclol, Pcd3, PCInterpret, SEF, Taiga, TenCore, Topic. The analyzed criteria have gathered considerable dust (and already had in 1989?), are in part completely out of date, and probably not even of historical interest any longer: Schamda notes, for example, whether the evaluated authoring systems allow colour display, underlining of text, or the generation of pictures with the help of fonts.

of America (NSF) for a period of five years at a cost of more than 10 million dollars. PLATO started as early as 1960, but was later supported by the NSF as well [Ford (1987); on the cost, cf. Shlechter (1988); s.a. Price (1989)]. Both systems were based on computer networks with terminals. Both were evaluated by the Educational Testing Service.

»For this kind of computer aided instruction in the sixties and seventies with mainframes, the teaching system most widely distributed over the USA was PLATO (Programmed Logic for Automatic Teaching Operation), whose development had started as early as 1960 at the Computer-based Education Research Laboratory (CERL) of the University of Illinois in Urbana-Champaign [...] There are 400 terminals for students and lecturers on campus today. Overall, 1300 terminals are connected to the PLATO network in the USA. More than 10 000 hours of computer aided instruction for over 100 subjects are available and tested today. Most teaching units were developed for instruction in information science. The production cost for an hour of evaluated instruction is as much as 20 000 US dollars« [Cyranek (1990), 121]. It is surprising that such a system could be realized at all, since the PLATO mainframes cost $3.000.000, and network cost alone was $2.500 a month [s. Tuttle (1992), 172].

One TICCIT server served up to 128 terminals, which were supplied with keyboards with special keys for Help, Example etc., and a colour television, one PLATO mainframe on the other hand could serve up to 1.000 terminals. A similar system is WISE (Interactive System for Education of the World Institute for Computer Assisted Teaching, WICAT). Today, there are certainly several hundreds of such systems for microcomputers. Kearsley, Hunter et al (1983a), and Kearsley, Hunter et al (1983b) mention further examples of authoring systems in large scale installations.

PLATO

PLATO was evaluated by the Educational Testing Service for five years in 162 school classes and five subjects. Bitzer and Skaperdas (1970) give a technically oriented report of the use of PLATO at the University of Illinois. A criticism which tries to project a didacticist image, but then goes into exclusively technical aspects after all, was expressed by Castle (1970) at the time. The fascination with the technical data (number of terminals, response times etc.) appeared overwhelming at first. There was no standardized learning program development for PLATO. In principle, every teacher could develop applications with the help of the authoring language TUTOR. For TICCIT on the other hand, standardized software was developed along the instructions of Merrill's Component Display Theory. O'Shea and Self (1983) go into the differences arising from this, but also into further differences in design between the two systems. In his summarizing report on PLATO development, Alderman (1978) comes to the conclusion: »a significant positive achievement effect was found for PLATO vs. traditional classroom procedures in the area of mathematics. No further significant achievement effects were found for any other subjects either in favor of PLATO or in favor of the regular classroom«. The few positive effects were apparently restricted to certain subjects and particularly to the use of CAI as an additional medium in instruction, a form of use called »adjunct CAI« by Chambers and Sprecher (1980). Whenever CAI was used as replacement for traditional instruction (»substitute CAI«), we get a different picture: »completed rates for the mathematics course dropped considerably below the traditional classroom, and student attitudes toward the CAI mathematics course were not positive« (336).

For the very subject in which positive effects of using PLATO were established, mathematics lessons, we have a comprehensive, both qualitative and formative evaluation report by Stake (1991), who reports her experience over the course of a two-year project with students and teachers. One of the aspects arising from this report is the function of the exercises and feedback in PLATO which are arranged in the manner of a game. An interviewed student states, for example: »It's the games that I like and also the things PLATO writes on top…« (87). Another point gained in the evaluation concerns the meaning of the teacher role within the overall context of the experiment: »PLATO reacted to many responses but could not cope with the problems in the way that Ms. Hamilton [the teacher, R.S.] did« (107). The students were not alone with the program, the teachers were always there to help and advise, which they apparently did frequently. A third point clearly illustrates the complexity of learning processes if affective and socializing factors are taken into account, which the program neither suggested nor treated, but whose discussion was left to the normal interaction in the classroom.

For these reasons, one can on the one hand rightly assume that learning with authoring systems which are fitted into the institution of school in this manner is not individualized learning in the sense that the originally behaviourist approaches had intended. On the other hand, the possibilities of these programs are limited. Certain complex aims cannot be accessed by their means. Thus e.g. Smith and Pohland (1991) report in the same volume on experiences from a similar experiment carried out in another school region. The report clearly points toward the discrepancy between instruction by computer and traditional classroom instruction in mathematics: »I wondered how closely the drills that they were taking correspond to what they were doing in class. Apparently it is not very close. Ruth told me that the day's classroom lesson was on 'writing mathematical sentences'. The drills, however, were all simple addition and subtraction problems« (24). So it seems even the students felt the discrepancy between program and classroom.

TICCIT

TICCIT is a special case in part, because this system was designed on the basis of Merrill's Component Display Theory [Merrill (1980)]. In a way, that puts the program with the ones discussed in the next chapter, which were designed on the basis of instructional design [I am going to come back to this]. TICCIT presents the concepts, procedures, or principles to be learned in three modes each: as a rule, an example, and as an exercise. For the exercises, the system supplies feedback with explanations. The learner can choose his degree of difficulty for rules, examples and exercises, and can ask for help for all three modes. A description of TICCIT illustrated by way of several screen dumps can be found in Merrill (1980).

The programs developed especially for mathematics instruction by the Institute for Mathematical Studies in the Social Sciences at Stanford University

[Suppes/Morningstar (1972)] are said to have been extremely widely distributed [Kearsley/Hunter et al (1983a), 91]. These are exclusively drill & practice programs and tutorials [Suppes/Morningstar (1970)].

The American military has been a stabilizing factor in the entire history of learning systems. Research on and evaluations of learning systems have been carried out at US Army Research Institute, Alexandria, VA [Perez/Gregory et al (1993)], and at the US Air Force Armstrong Laboratory, Brooks Air Force Base, TX [Muraida/Spector (1992)]. CBT systems like TICCIT and PLATO were used and evaluated on a large scale in the army as well, as were instructional systems and intelligent tutoring systems ten years later, e.g. with ASAT (Automated Systems Approach to Training) [Perez/Gregory et al (1993)]. Shlechter (1988) deals with the evaluation of CBT systems from a military perspective. Central arguments for the use of CBT from the army point of view were a supposed reduction of cost for the trainer and an allegedly proved saving of time for the trainees. Shlechter reports many studies on the use of CBT in the army, and points out the inconsistency of results and the lack of replication possibilities.

TAIGA

TAIGA (Twente Advanced Interactive Graphic Authoring System) is a Dutch development in the area of authoring systems for PCs and has, at least in the Netherlands, found a comparable distribution as that of PLATO in the USA. TAIGA did not seem to have reached a first state of completion until 1988 [Bosch (1988)]. TAIGA consists of more or less independent subsystems which are organized in a hierarchical structure on three levels, each with its own editor. Level 1 serves to structure the course contents by way of a module editor; level 2 serves to structure instructional interaction by way of an episode editor, and level 3 designs the course contents with a text and graphics editor. External programs can be integrated into the learning program. TAIGA consists of four subsystems which (1) serve to edit learning programs, (2) control students' access to the software, (3) control access to other systems and data bases, and (4) create protocols of the learners' interaction [s. Pilot (1988)].

SHIVA

As late as the mid-nineties, the development of the authoring system SHIVA, which is supposed to combine multimedia and an intelligent tutoring system, was supported with enormous sums by the European Community. SHIVA originated as a combination of a French authoring system (ORGUE) and an English tutorial authoring tool (ECAL) which allowed adaptive instruction [O'Malley/Baker et al (1991)]. That makes SHIVA not just an ordinary authoring system, but a multimedia environment which, apart from ORGUE as frame editor and PSAUME as graphic editor for the lessons, also has editors for images, graphics and sound, as well as a simulation interface at its disposal, and on top of that integrates a special editor for adaptive tutorial processes with ECAL [Elsom-Cook/O'Malley (1990)]. ECAL stands for »Extended Computer Assisted Learning«, and was designed by its authors as a piggy-back extension to authoring systems, as »experiment in ITS minimalism«. As a hybrid system, SHIVA could be treated in the chapter on authoring systems as well as in the chapter on intelligent tutoring systems, although it is basically intended as an authoring system as far as its function is concerned.

I wonder why the developers of SHIVA made the decision to furnish the system with its own editors for image and sound. There exist much more efficient variants for these functions, which are available commercially and whose products are easy to import via common exchange formats, a principle on which even commercial authoring systems like AuthorWare or Macromedia Director rely. In all probability SHIVA will have been long overtaken by the operating system evolution (integrated components for the synchronisation of time-dependent processes, for speech recognition and speech synthesis), the evolution of commercial authoring systems and the development of new standards (e.g. for the compression of digitalized films, navigable film formats, platform-independent image formats, compression methods) once the first applications could be developed with this hybrid authoring tool.

Expectations and Prognoses

One problem of authoring systems is the developing cost. One had initially expected that the developing cost would pay for itself in the long run by repeated use of the programs. But as early as 1980 it was foreseeable that the taking over of ready-made teaching units by the teachers would prove to be an insurmountable problem: »The single most critical issue in CAI today is the development and sharing of quality CAI materials« [Chambers/Sprecher (1980), 338]. In view of the developing expenditure and the cost of CAI units, a wider distribution would be needed, but »the available courseware is difficult to share and, in many cases, protected by copyright if of significant value«. Chambers and Sprecher remind us of the many prognoses foretelling a brilliant future for computer aided instruction, and that the Carnegie Commission prognosticated wide acceptance and a mass of products for the year 1980 in 1977, »however, widespread acceptance and use of CAI has not yet occurred« (339).

Nevertheless, Kearsley, Hunter et al (1983a) and (1983b) come to a positive view of the development in their overview of more than 50 systems for computer aided instruction between 1959 and 1982: »There is ample evidence that computers can make instruction more efficient or effective« (90), although two other conclusions they draw show clearly that this alleged success must apparently be due not to research efforts, but other factors:

- »We know relatively little about how to individualize instruction«
- »We do not have a good understanding of the effects of instructional variables such as graphics, speech, motion, or humor«.

Even in 1986, Leiblum (1986) offers a formal overview of the sate of authoring systems in the Computer-Assisted Learning (CAL) group at the University of Nijmegen in his essay »A Decade of CAL at a Dutch University«, and presents a list of 31 projects, of which 10 are in regular use, 13 abandoned or already finished, and 8 still in development. The developers in Nijmegen preferred the *Planit* system, and later switched to *TenCore*. But only eleven of the programs listed are being developed with *Planit*, only two with *TenCore*. Most of the applications are tutorials. But Leiblum assumes that simulations will increase.

Hawkridge (1988) presents an enthusiastic overview as late as 1988. He is convinced that the success of CBT is inevitable: »Our research of the last two years has led me to predict that more than half of the large and medium-sized companies in Britain and the United States will be using CBT in some form, for some of their training, before the year 2000« (41), although he must admit that »80 percent of the CBT material we have seen is poorly designed«. Poppen and Poppen (1988) are also convinced of the behaviourist approach's strengths, and want to take over some its elements into modern CAL programs.

In the same year, Euler and Twardy (1988) speak of the failure or stagnation of a successful distribution of CBT[7]. They put the failure down to both the technical immaturity of the systems and the »lack of didactic imagination which alone can guarantee quality or ensure acceptance that had killed off computer-assisted learning« (91). But as early as 1990, Euler (1990) again speaks of a »renaissance of CAL« and »resurrection of CAL « (179), and emphatically ascribes to it the following three important characteristics (184ff):

- »CAL comprises special possibilities of presenting learning matter and thus fosters its vividness!«
- »CAL possesses special possibilities of learner motivation!«
- »CAL enables an individualization of learning!«

He concedes, however, in his closing judgement that the realization of these aims is decisively bound up with the »author's didactic imagination« (187): »In the end, CAL is only in good hands with educators who are good educators without the computer as well!« (188) Nissan (1989) also laments the lack of didactic imagination, and supports his complaint with the observation and judgement »that CAI and ICAI systems as they are today usually with a boring interface, based on text only interaction, or possibly even with poorly designed graphics, may prove even detrimental, didactically, just like dull teaching« (68).

McDermott Hannafin and Mitzel (1990) collect the following negative features in their overview: The development of teaching units was too costly, the requirements for units which would have been necessary from a didactic perspective were sacrificed in the interest of better realizability, there were considerable problems in programming, the role of the information scientists involved was overrated, and there was a lack of efficient authoring tools. They demand of future authoring systems that they must be open and allow for a design which centres on the learner.

The Structure of Authoring Systems

The term authoring systems was meant to suggest to the customer that one could easily develop learning programs with the help of these systems. The term »author« alone already suggests that one can »write« learning programs

7. On the decline of Programmed Instruction in Germany cf. Gorny (1982), 346ff and the positions quoted there.

without having to possess any programming skills. All the user of an authoring system must do – at least according to the ideal type of this kind of program – is to input his expert knowledge in the form of questions and foreseeable correct and wrong answers, and the authoring system will automatically create a learning program. The authoring system acts as a program generator in this case. Once the learner gets access to the program, the authoring part is faded out and the authoring systems acts as just a presentation machine.

The relatively low degree of difficulty in using authoring systems results from the fact that the author does not have to possess any programming skills. This is possible because the authoring system sets a fixed algorithm according to which the units must run. Simplicity is thus paid for by restrictions in performance (more powerful authoring systems go back to using a simplified programming language for that reason). In spite of this attractive user philosophy, the concept did not work. Rode and Poirot (1989) have established in a survey of 200 Texan teachers that teachers do not use the authoring systems on offer. Although the teachers had been in their job for some time and had received appropriate education, only 16% of the mathematics teachers and 11% of other teachers had written a learning program at some time (195).

But the expectations teachers, who are mostly laymen in the area of computing, have of authoring systems corresponds to the propaganda. Teachers do not expect originality, powerfulness, or a valuing of the didactic concepts in authoring programs, but to be able to easily develop software for teaching purposes (»Teachware«) with the help of authoring systems. In Rode's and Poirot's survey, »ease of editing« heads the ranking scale (196). These expectations easily overlook that small difficulty in developing teaching materials is dearly paid for by a restricted didactic concept of the resulting Teachware [cf. Voogt (1990), who examined teachers' criteria for their choice of program in physics].

Despite CAI's claims of enabling anyone to be an author of CAI lessons using easily managed programming languages, one had to reach the conclusion that the concept of the autonomous lecturer as author of teaching and learning software was mere fiction: »The notion that computer-based materials can be produced by anybody, completely by themselves, is an archaic concept« [Bork (1979), 20]. The developing problems in CAI lie partly in the treatment of subject matter (learning objectives, segmentation, feedback), and partly in the programming languages. Streitz (1985) also points out that even »the authoring language is still very much oriented towards the pattern of programmed instruction « (57).

Taylorization

Because of the low requirements regarding system or programming skills, it is easily overlooked that authoring systems, because of their orientation towards the behaviourist model of learning, at least expect of the authoring university teacher that he has mastered the mechanism of breaking down the subject matter into very small steps, of structuring these small steps in a meaningful sequence, and providing appropriate feedback (or reinforcement) for the learner's success or failure. The next step must be based on the previous one in such a way that the student will not get stuck in the middle of the program because of too great gaps or jumps. The reasoning steps expected by the teacher must not be too great, because otherwise gaps could arise in the sequential structuring of the subject matter, or in the intellectual organization. For that reason, authoring programs continually run the risk of falling prey to suggestiveness and triviality. The answers to choose from must not be absurd, and have to be relevant to both subject matter and question. Through this segmentation of the learning process, a kind of »Taylorization« of subject matter and learning process occurs. One needs immediate reinforcement and correction in order to keep up the learners motivation.

These methodical and didactic aspects of working with authoring systems are – at least if you follow behaviourist theory – not trivial, but they are all too easily underestimated by the teacher who votes for authoring systems because of the apparent ease in developing teaching units. The expenditure in time needed for the development of reasonably qualified products is accordingly high. Thus Ottmann (1987) reports »that one must invest about 80 to 120 hours into the development of a one hour lesson« (65). This estimate seems to be on the lower end of the scale to me. Chambers and Sprecher (1980) state developing times of 50 to 500 hours per hour of program time (337).

Answer Analysis

In judging the quality of authoring systems it is very important which modalities the system offers to the learning program developer with regard to choice of questions, types of question-and-answer, types of evaluation (answer analysis) and forms of branching [Fankhänel/Schlageter et al (1988)]. The choice of questions can occur in sequence, at random, or in mixed forms. The generally distinguished types of question-and-answer are:

- yes/no (right/wrong)
- multiple choice
- completion text
- free answer, and
- variants of these basic forms.

Most often preformulated forms of answers, i.e. buttons, menus, dialogues, are scheduled, in order to keep control over the input and facilitate analysis. Answer analysis of free text input is problematic. The entered answer is usually only checked for correspondence, exactness, or for synonyms. Understanding the sense of the learner's input is impossible, the best one can do is tolerance regarding orthography. This is a decisive point for a methodological and learning theoretical evaluation of authoring systems. Since they make learning progress dependent on answer analysis, it makes absolutely no difference how

'Socratically' or apparently open and liberally the questions for the learner are put, because the check for correctness must in any case be carried out according to the forms of correctness described above.

The exercise presented to the learner on the screen consists largely of a sequence of input, questions, and a number of preformulated answers, out of which the learner can choose one or more and mark them. Depending on the learner's answer, the preplanned mechanisms of the exercise program are then put into motion, e.g. confirmation of correctness and presentation of the next question, or repeating the previous question and showing an advisory text or comment, etc. The concept of »corrective teaching«, which is based on diagnosis models [Boulet/Lavoie et al (1989)] which determine the deviation of expectation and realization, goes beyond this.

There are many sensible uses for drill & practice programs, e.g. with the frequent repetitive processes in learning foreign languages, or in learning how to operate machines. A knowledge component with rules and diagnostic procedures can make up for a lot of the negative effects of the drill & practice approach here. Just look at an example of a trainer for language articles in Kurup, Greer et al (1992), which demands from the student the correct choice of article and a corresponding rule. But even if the lessons apparently take place as a graphic »adventure« in the form of an animated sequence of images, the program will in the end evaluate the learner's actions according to the right/wrong principle, and will branch back to the initial question if wrong answers occur. In the actual learning part of the program, the basic structure of programmed learning is thus preserved.

There is no possibility of adapting the course of a learning program created by authoring systems to the learner's reasoning. The process of learning is broken down into very small steps, which have to be passed in strict order. Learners therefore frequently feel as if in a straitjacket, because the strictly sequential order hinders subjective associations, makes thinking ahead futile, indirectly forbids any thoughts on the overall aim, and simply deflects any conclusions directed toward the final solution of a problem. If the programs follow the multiple choice pattern even half-way, and implement the feedback mechanism, then one can safely assume that the behaviourist basis of the authoring systems [Bodendorf (1990)] will be reinstated beneath the attractive surface through the obligation to a Taylorization of the subject matter, the condensation of the learning process into a question-and-answer structure, and the process of checking answers [cf. Streitz (1985), 57]. The efficiency of these learning systems [s. the overview in Kulik, Kulik et al (1980a)], moreover, is not as great as the expectations cherished in this regard: »It is interesting to note that only short-term effects are ascribed to it [computer aided instruction, R.S.], which moreover are suspected of being overlaid by the Hawthorne effect of the 'novel'« [Fischer (1985), 69].

Didactic studies pointing out the necessary differentiation according to types of learners [e.g. Goldman (1972), Pask/Scott (1972)] can explain, why learners develop a reluctance to work with more programs of this kind after an interval of curiosity about the new medium: If such learning programs may be just about suitable for students who learn mostly sequentially, they are totally unsuited to holistically oriented thinkers, who have a heuristically founded cognitive problem-solving behaviour at their disposal. Moreover, the embedding of cognitive learning strategies into social contexts and motivational conditions must be thought of.

Courseware and Multimedia

One has tried to improve the simple structure of authoring systems by integrating animations and simulations [Ottmann (1987), 64]. There are several attempts to put authoring systems on top of expert systems, such as the Eurobench Workstation [Stratil (1989)]. These attempts often aim at a natural language user interface [on such systems from a psychological perspective, see Spada and Opwis (1985), (14ff)], and they try to analyze free answers with more sensitive evaluation instruments and let the programs react with more branching and advisory strategies. In these cases, however, the teacher's developing effort is higher once more [Anderson/Boyle et al (1984)]. But as long as one insists on checking the learner's reactions and making the program's progress depend on this check, no amount of differentiation will change the basic behaviourist pattern. Even if computer aided learning programs like open courseware try to avoid some of the grossest errors of Programmed Instruction, the roots in behaviourism are still discernible: »Interactive instruction (computer-assisted instruction, interactive video) is often an extension of programmed instruction developed in the behavioral psychology era« [Merrill/Li et al (1992a), 15].

Courseware

Today, one has given up the evaluation mechanism of authoring systems as a rule, and thus gains more open systems for the development of courseware. The learning programs developed by free use of authoring systems such as *Macromedia Director* or *AuthorWare*, which are not committed to any specific methodical school, have basically had more educational success than strict authoring programs. For this kind of program, the term courseware has become common: »Tutorial courseware is basically a mis-application of the programmed learning model of instructional design« [Jonassen (1988b), 152]. The term, commonly used in American English, is however more of a product category than a scientific term: it is used largely synonymously with CAI and CBT today, and covers tutorials, drill & practice programs, simulations and multimedia programs. Nevertheless, there are continual attempts to clarify the differences by definitions. Thus Christensen and Bodey (1990) try to tackle the difference between courseware and computer aided instruction (CAI). Thus

Bodendorf (1990) depicts e.g. the transition from Programmed Instruction to discovery learning (28ff). The transition from courseware as computer aided instruction and audio-visual learning to multimedia learning environments is described by Allen (1994). An early use of the term multimedia in connection with courseware can be found in Briggs, Campeau et al (1967). Bonner (1987) recounts the transition from frame-based courseware to expert systems and intelligent tutoring systems. Further developments will be discussed in connection with industrial design and intelligent tutoring systems. For some years, so-called Interactive Video was discussed as a separate species. But interactive laser disc technology is basically no more than an addition to frame-based courseware in form of a laser disc. An overview of evaluations of interactive laser disc systems can be found in Kearsley and Frost (1985). In 1984, more than 200 laser discs existed in the educational sector (7), but it follows clearly from the report that good interactive laser disc courseware was rare even in 1985.

The growing demand for courseware in comparison to the demand for Programmed Instruction products may be due to the fact that the targets of courseware are much wider: »The most familiar and pervasive uses of computers in education are the often derided, scorned, and ridiculed drill and practice and the tutorial modes« [Nix (1990), 145]. There are even programs on such difficult topics as e.g. mastering practice skills for social workers [Seabury/Maple (1993)], mastering scientific argumentation [Bork (1993)], mastering the skill of listening [Cronin (1993)], and improving communication skills [McKenzie (1993)]. Courseware applications cover virtually all school subjects, educational branches and academic courses. We find courseware in law, physics [Bork (1980); Richards (1992); Glover (1989)], history of art, social work [Seabury/Maple (1993)], foreign language learning, biology [Hall/Thorogood et al (1989); Huang/Aloi (1991); Kramer (1991)], medical education [McCracken/Spurgeon (1991); Guy/Frisby (1992)], pharmaceutics [McKenzie (1993)], librarianship [Bourne (1990)], etc.

Program Categories

In computer aided learning, the following program forms are usually distinguished: drill & practice, tutorial, games, simulation, and problem-solving [Chambers/Sprecher (1980)]. O'Shea and Self (1983) distinguish 11 different software types in all: linear programs, branching programs, generative computer aided learning, mathematical models of learning, TICCIT, PLATO, simulations, games, problem-solving, emancipatory modes, dialogue systems. One recognizes instantly that the classification was not carried out according to a unified principle: practical authoring systems (PLATO, TICCIT) are put at the same level with application types (games and simulations), while there is a distinction of programs within Programmed Learning (linear vs. branching programs). Schaefermeyer (1990) gives an idea of the various types' distribution: »as of 1985, about 50% of the software developed to that time had been drill and practice; tutorials accounted for about 19%, games about 12%, and simulations about 5%« [cit. in Bialo/Erickson (1985)]. He criticizes that »much of the present computer instruction is about computers rather than with them« (15).

Feedback

Early studies on Programmed Instruction depicted the concept as successful. Repeat studies on Programmed Instruction showed that success falling off. Is program control, the schematic nature of feedback, the reason for this? Fischer (1985) distinguishes »hit feedback« from »miss feedback« (69) and points out that many systems introduced explicit miss feedback. »This may be the reason for the failure of early CAI: the introduction of miss feedback could in no way heighten the feedback's information value, the only thing to be heightened were the punishing, aversive contingencies« (69).

Motivation and Feedback

We must distinguish two feedback sources: Feedback on the task, which according to Skinner is primarily meant to serve the learner's motivation, and feedback on actions within the user interface. The former does not seem to be particularly successful in the long run: »After continued use of CAI, complaints about boredom are voiced; teachers report flagging student motivation. Surprisingly, CAI methods are weak in the exact area in which they should be particularly efficient according to Skinner: the area of motivation« [Fischer (1985), 69]. The latter form of feedback may be responsible for a part of the computer's attractiveness to young people. Fischer criticizes the analogization of Skinner's operant conditioning with program feedback (70).

Informative Feedback

Cohen (1985) sees remains of the behaviourist feedback concept even in courseware: »One of my major sources of disappointment in a CBI program is the use of feedback […] A reason for this might be that most instructional designers of today come from a predominantly operant psychology background, where behavioral theory and programmed instruction have dictated the approach« (33). There are other possibilities in his view, because with the transition from behaviourism to cognitivism, a transition from immediate feedback to correct stimulus response to informative feedback had taken place, which was supposed to identify mistakes and report them to the learner.

Fischer (1985) warns, however, especially with regard to the informative feedback put so much to the fore by Cohen, »that we must expect even with ever so factual feedback that it will not always be interpreted as pure information, but always as 'rewarding/punishing', that is affectively as well «. Intelligent tutorial systems, which understand feedback one-dimensionally as informative feedback, can make crucial mistakes here: »Thus, a one-dimensional emphasis on 'information' vs. 'reinforcement' can lead to just as negative effects in the design of feedback components, as did the exclusive foundation of CAI in Skinnerism« (81).

Implicit and Explicit Feedback

Fischer and Mandl (1988) distinguish like Cohen between the feedback concept in behaviourism and that in cognitivism: in behaviourism, they characterize feedback as the conditioned connection of behaviour and reward, while in cognitivism feedback has taken on the meaning of informative feedback on behaviour with regard to the objective to be reached. They criticize behaviourism for neglecting the information content of feedback in the conditioning principle. They criticize cognitivism for neglecting the accompanying affective and motivational processes of feedback (190). They are interested in the question why there are still negative effects of feedback even if it is used extensively. Feedback can have an implicit (»covert«) and an explicit (»overt«) component. Fischer and Mandl point out that even expert systems, which do not provide explicit feedback, do provide an implicit feedback (»covert self-feedback«), especially if they possess diagnostic skills (194), and that even tutorial systems, which consciously give out feedback in small doses for motivation psychological reasons, give feedback on inappropriate actions: »At present according to our knowledge, no empirical study has been done on the possible punishing or demotivating effects of a bug-diagnose series in a BUGGY system or has examined the possible lowered diagnostic power of a WEST architecture« (195). They warn of the consequences uncontrolled feedback in diagnosing systems might have: »covert feedback may be of more harm than instrumental use to the learner […] might impede and prevent learning rather than assist it« (195ff).

They think that implicit feedback should be counterbalanced and controlled by explicit forms. In KAVIS II, an interactive laser disc system on the structure of plant cells, Fischer and Mandl have tried to strongly differentiate the feedback components in different learning phases with regard to possible effects on learning: Initially, feedback should not be aimed at marking mistakes, but should provide information help on the subject matter in audiovisual form, while in more advanced learning phases, feedback should consist of corrective 'metacognitive' help and direct information on the subject matter with the aim of self-correction. Natural feedback can also have positive effects, as the study of Park and Gittelman (1992) demonstrates, in which a group of students received natural feedback, while another received explicit help, and there proved to be no difference between the two groups: »This suggests that intentionally mediated feedback may not be necessary if the student receives natural feedback directly from the system« (36). This result may be seen as a plea for interactive programs which allow for direct manipulation of graphic objects, from which feedback follows automatically.

The questions asked of the use of feedback in learning programs can not be too subtly differentiated. Park's and Gittelman's study points out, for example, that visual feedback in animated form may be superior to feedback in static form. Maybe we must vary feedback according to types of learners as well, or vary immediate feed back, delayed feedback, or feedback provided at the end of a session [Cohen (1985)]. Pridemore and Klein (1991) varied »elaboration feedback« and »verification feedback«. In the elaboration mode, students received the correct answer and an explanation after each question, in verification mode merely an indication whether their answer was correct or wrong. Elaborated feedback proved to be superior.

What has not been asked in the studies discussed so far, is which form of feedback the learners themselves would prefer, if they could choose. This question has been examined by van der Linden (1994). She examined the effect of corrective feedback with a traditional drill & practice program for foreign language learning. The interactions of the 23 students were recorded in their entirety, and protocols of audible reasoning were analyzed as well. She established three strategies of learners: almost half of the students followed the »optimal« sequence of »response–feedback–retrial«, some only let the correct answer be shown to them and then quickly went on to the next exercise, others noted neither feedback nor correct answers. The interviews confirmed the impression the author got out of her analysis: ambitious students went rigorously through the optimal sequence, impatient students followed the third strategy [s. however Sales/Williams (1988)].

Exemption from Punishment

Why are not all learners impatient? Why do they not react negatively to permanent feedback? Weizenbaum's ELIZA [Weizenbaum (1966)] already provides a good example for answering this question: despite dense feedback, the computer is not experienced as control. But as soon as the feedback assumes a hint of control or correctiveness, the learner retreats. Fischer and Mandl emphatically point out the unintentional punishing effect that feedback can produce. This brings us back to the criterion of exemption from punishment, which I counted among the factors responsible for the success of computer programs with young people in Chapter 2.

Design Guidelines for Courseware

Design guidelines will be discussed not only here, but also in the chapters on hypertext and electronic books, with regard to the respectively discussed software types. I will restrict myself to citing three studies here which have formulated design guidelines for multimedia. I do not want to discuss the problem adhering to such guideline catalogues, i.e. their vagueness, their being rooted in subjective experience, and their low degree of operationalization.

Cates (1992) establishes 15 guidelines for designing hypermedia:

Match current curricular emphasis

Match current teaching practice

Match current instructional time restraints

Provide the capability of tailoring the product to meet specific teacher needs

Make the database easily accessible for use as a research toll

Make the database expandable

Design the product so that it helps learners develop their inquiry skills

Encourage learners to think about what they know and what they are learning

Design a 'user-friendly' learning environment

Think of a videodisc as more than just a full-motion repository

Include video segments that make effective use of the medium

Be careful to use good writing and correct spelling and punctuation

Make the product interactive in meaningful ways

Emphasize context, not just isolated facts

Provide print materials that are at least as valuable as the multimedia database.

Schaefermeyer (1990) lists 16 design guidelines for courseware:

»Design of learning activities should include:

– Specifying the target audience

– Specifying entry level learner competencies

– Stating objectives behaviorally (performance)

– Informing the learners of objectives

– Determining the range and scope of the content to adequately achieve intents

– Employing content learning in the instructional approach

– Using appropriate vocabulary for the targeted learner

– Stating instructions clearly

Identify the curriculum role used: Adjunct, mainline, or management

Identify mode of instruction to be employed which will best achieve the objective: Drill and practice, tutorial, game, simulation, problem solving

Use of branching

Make the program menu driven

Format instructional text for screen display

Embed graphics into the content

Use cues and/or prompts

Grant user control to learner

Employ teacher management of instruction

Use feedback appropriately

Use random generation

Consider classroom and instructional time

Provide instructional teacher's manual and student manuals

Use technical design that allows for quick response and quick loading

Provide for evaluation monitoring« (10).

Mayes (1992a) names guidelines for representation in multimedia systems: the mental model should find a realistic or dynamic form of representation in design, one should choose a graphic or auditory form of realization, an the I/O modalities have to be suited to this in turn, as they have to be suited to the learning objectives. Two or more media using the same channel of reception or the same processing capacity should not run at the same time, and the modality should change often (15).

I will let these recommendation catalogues stand here without any further commenting, and consider it the reader's task to deal with them. To be quite honest, such »design guidelines« trigger very few ideas in me.

CHAPTER 5

Administered Learning

Models of Instructional Design (ID)

Theories of instruction or instructional design are historical reactions against behaviourism: they originated in the early sixties[8] and aimed at higher learning objectives than learning by association. They sought to define learning objectives cognitively, and to promote these learning objectives with more variable methods. Criticism of Programmed Instruction and its limited branching possibilities nurtured the idea of achieving a more effective form of individualization by introducing an increased variation of methods. A sub-goal – still suggested by authoring systems – that played a role here was to generate automated production of learning units by simple deduction from learning objectives and prescribed methods.

Bruner and the ASCD

Although Bruner (1966) only wanted to illustrate the pedagogical consequences of cognitive psychology and did not intend founding a new theory, he may not only be responsible for popularising the concept of discovery learning, but also, since he provided a first approach for a theory of instruction in his book »Toward a Theory of Instruction«, for the change from learning theories to theories of instruction that occurred in US psychological research and the Association for Supervision and Curriculum Development (ASCD) from 1965 onwards [Snelbecker (1983), 445]. Generally, however, Gagné, Ausubel and Scandura are considered the true founders of the theory of instruction. Seels (1989) gives a detailed historical synopsis of the development of instructional psychology and presents a timetable of the years 1954 to 1980.

8. Andrews and Goodson (1980) offer an excellent summary of the developments in instructional design, which took place as early as 1973 to 1978 (3). In a table, they compare as much as 40 different models for instructional design which show, with varying emphases, descriptive, prescriptive, predictive and/or explanatory aspects, and they ascribe explanatory capabilities to those models based on theories of learning. They do this although they themselves explicitly point out the difference between the terms “model” and “theory”.

Gagné

Gagné's work »Conditions of Learning and Events of Instruction« [Gagné (1965)] is usually recognized as the first theory of instruction with lasting practical effects. In historical perspective, his model of instruction, often called Instructional Systems Development (ISD) [Merrill, Li et al (1990a), 9], was simply an attempt to relate the existing learning theories to each other and to assign to each theory its relative position with regard to their diverse learning domains, assigning appropriate positions to the behaviouristic approaches of Thorndike and Skinner in the process. Snelbecker (1983) emphasizes the eclectic character of this approach and the fact that Gagné set great store by behaviouristic theories: »This is a comprehensive and somewhat eclectic theory in that it draws from many aspects of psychology learning theory, although its major knowledge base is the more traditional behavioral theories with comparatively little influence from contemporary cognitive psychology theory« (457). Case and Bereiter (1984), too, emphasize the behaviouristic origin of Gagné's research.

In spite of Gagné's origins in learning theory, we can recognize a distinct switch towards instruction [Snelbecker (1983)]: »Though the basis for classifying educational tasks is explicitly derived from certain specified aspects of learning research and theory, this theory is oriented more towards instructional events than merely towards changes presumed to be occurring inside the students« (457ff). Gagné bases the main part of his approach on Bloom's taxonomy of learning objectives, and in this approach integrates the different learning theories developed up to then, from behaviourism to cognitivism. He distinguishes intellectual capacities, cognitive strategies, verbal information, attitudes and motor capabilities, using finer differentiation between lower capacities than in the realm of cognitive capabilities: »There is some tendency for the Gagné theory to emphasize comparatively low-level to moderately high-level educational goals« (458). Gagné assigns specific »instructional events« and a specific area of validity to each of these goals, to associative principles of learning as well as to the higher, more complex learning processes, which form a kind of ascending ladder, so to speak [Scandura (1983), 226; Reiser/Gagné (1982), 507]. From a methodological point of view, the result – often described as taxonomy – might be called a kind of categorial grid for different theories, or a non-deterministic set of rules for pragmatic teaching decisions. Gagné's model is not so far operationalized that it does no longer offer any scope for interpretation. Practical decisions and responsibility for the translation remain with the teacher. The heuristic value inherent in such categorial grids be uncontested, but the collection of approaches which Gagné unites under one roof is too heterogeneous and eclectic to form a theory.

Gagné, Briggs et al (1979) expand this approach into a construction they call *instructional theory* [Aronson/Briggs (1983)]. The five types of learning events are each asigned a dimension of previous knowledge as internal condition and a learning environment dimension as external condition, and the learning process is reconstructed as a sequence of instructional events: gaining attention, informing the learner about the learning objectives, recalling learning qualifications, presenting new information, counselling the learner, demonstrating new skills and exercising them, feedback, checking performance, augmentation, and transfer. Gagné's approach has found followers in the eighties as well, e.g. in Roblyer's (1988) model for planning instructional design. An addendum to the model by Wager and Gagné (1988) concerns the integration of a categorial concept of stages of learning for learning with computers: defining goals, prototyping, programming, and evaluation, each stage having its own revision cycle.

Gagné's and the instructionalists' main motive for developing a theory of instruction, after the phase of criticism of the assiociative learning of behaviourism and Programmed Instruction, lay in avoiding an atomization of learning through stimulus-response-connections and the resulting Taylorism of Programmed Instruction, as well as in making the planning of computer-aided learning units more variable by way of different teaching methods. The plan of instructional theory or »Instructional Design«, to put the technique of authoring systems onto a more variable footing through construction principles whose foundatons were developed in the sixties by Ausubel, Gagné and Scandura, seemed both necessary and sensible: »The problem is that most of our current attempts to use computers for instruction are too simplistic to have significant effects on learning. We need much more sophisticated instructional software to really help people learn via computers. More specifically, we need to be able to incorporate the kind of teaching strategies and subject matter knowledge possessed by good teachers into our programs« [Kearsley (1987), v]. What was intended, then, was mainly a differentiation of the programs in terms of learning objectives, methods and didactic strategies.

Many researchers not only pointed out that the origins of instructionalism lie in behaviourism, they also mentioned the fact that instructionalism was not able to dissociate itself wholly from the technological basis of computer-aided instruction and thus retained some of the features of behaviourism. This is also emphasized by Winn (1990), for example: »Instructional designers generally acknowledge the behavioral origins of their field« (54). This is also emphasized by Park, Perez et al (1987): »The early paradigm of instructional systems development (ISD) was strongly influenced by a behavioristic approach to learning« (14). Lowyck and Elen (1992) see a close relationship between behaviourism and instructionalism in two points in particular, a general orientation toward learning as behaviour, and the adoption of behaviourist learning principles (associative learning and feedback): »Both the behavioristic origins and the general systems theory strongly influenced the outlook of ID […]. While in ID the design parameters are selected from a behavioristic framework, the process is structured in line with general systems theory« (131). The orientation of the concept towards a systems theory, called »a one-sided effectiveness and optimizing impetus« by Weidenmann [(1993), 6], makes ID take the leap from a behaviourist to a functional instruction concept (4).

Scandura

Scandura's »Structural Learning Theory« (SLT) [Scandura (1973)] deals with the selection of instruction methods and sequencing of subject matter by way of rules. Prerequisite for this is a structural analysis of the subject matter, in order to determine the rules to be learnt by way of examples (Scandura treats rules as learning objectives). In Scandura, subject matter is represented only in the form of rules. The learner, too, is represented exclusively in the form of rules of a higher or lower order, and a few universal features like processing capacity and speed [Scandura/Scandura (1988)]. Both diagnosis and instruction are based on these rules. Knowledge and decisions are treated deterministically in the system, i.e. rules are either undetermined or available/not available. In Scandura's opinion, rule-based systems are better suited to the control of learning programs that expect a high degree of variability and are supposed to generate tasks ad hoc. Scandura and Scandura (1988) want to replace CBT authoring systems with »fixed content« with generative authoring systems, »in which content is generated dynamically« (347). Scandura's approach, which he calls a theory of learning, is a little different from instruction theory and already develops in the direction of algorithmic learning systems [Landa (1983)] and intelligent tutoring systems, as its own prototype, *MicroTutor*, demonstrates. Scandura's theory seems to be especially suited to individualized instruction, which includes instruction by way of computer programs, and to the mastering of subject matter that can be algorithmicized.

As an example of a program developed on the basis of the Structural Learning Theory, the Scanduras demonstrate *MicroTutor II Arithmetic Tutor* for the Apple II by Intelligent Micro Systems (1982) [Scandura/Scandura (1988)] and the authoring system PRODOC. The arithmetic tutor can analyse what a student knows or does not know, and it can decide on the optimal learning sequence the student needs in order to improve his knowledge. The tasks for this are not taken from a fixed store, but are newly generated. The diagnosis of rules and the instruction for rules are strictly separated, a fact the authors still see as one of the »major conceptual limitations« (353) of their approach. As a further limitation, they cite the fact that the tutor is limited to single rules in the instruction, and thus cannot be expanded to rules of a higher order. These limitations lead to the evaluation that »the basic design of the system reflected the Structural Learning Theory in only general terms. Consequently many features were fortuitous and opportunistic«.

Anderson

Anderson's ACT* (Adaptive Control of Thought), [Anderson (1983)] is an architecture for a production model that is meant to simulate human cognition. The ACT theory assumes that long-term memory is made up of a network of linked propositions. The learner continually adds new propositions to the network. Each new proposition only forms a weak link, which has only a low probability of being activated on demand. Only if the learner encodes multiple propositions which are partially redundant, the probability of their being remembered improves.

»Originally inspired by S–R association principles, this theory currently is based on productions (condition-action pairs). Even today, however, it retains such S–R constructs as ‘strength,’ ‘spreading activation,’ and ‘probability’« [Scandura/Scandura (1988), 374ff.]. Glaser (1990), too, stresses that the instruction strategies in Anderson’s ACT* are strongly reminiscent of Skinnerian principles. The close observation of the student by the tutor, the immediate feedback, and other strategies of the system are almost identical to the behaviourist principles of Programmed Learning. Anderson’s LISP-Tutor [Anderson/Reiser (1985)], a practical application of his theory, has been criticized accordingly. His model, also known as elaboration hypothesis, is used as theoretical and methodical basis of many applications both in the field of instructional design and that of intelligent tutoring systems. The model starts from the assumption that learners must elaborate their thoughts in reading in order to have a better chance of understanding what they have read.

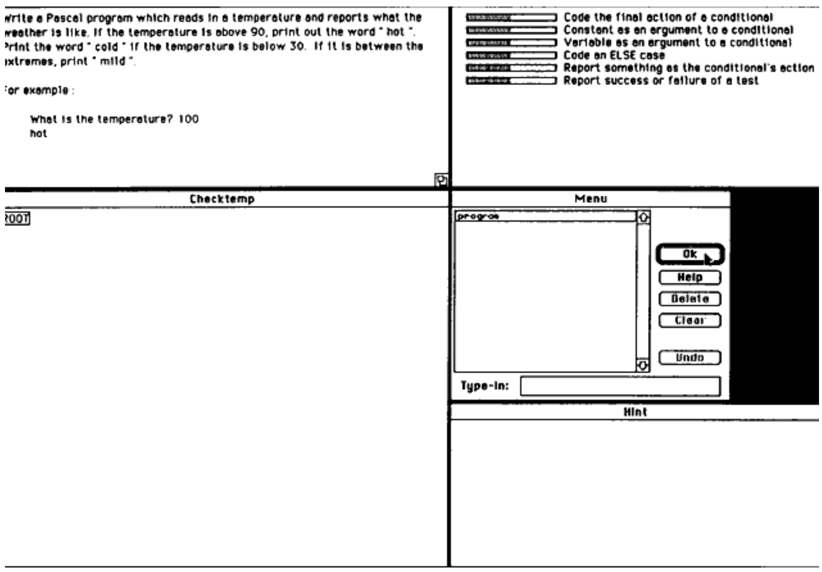
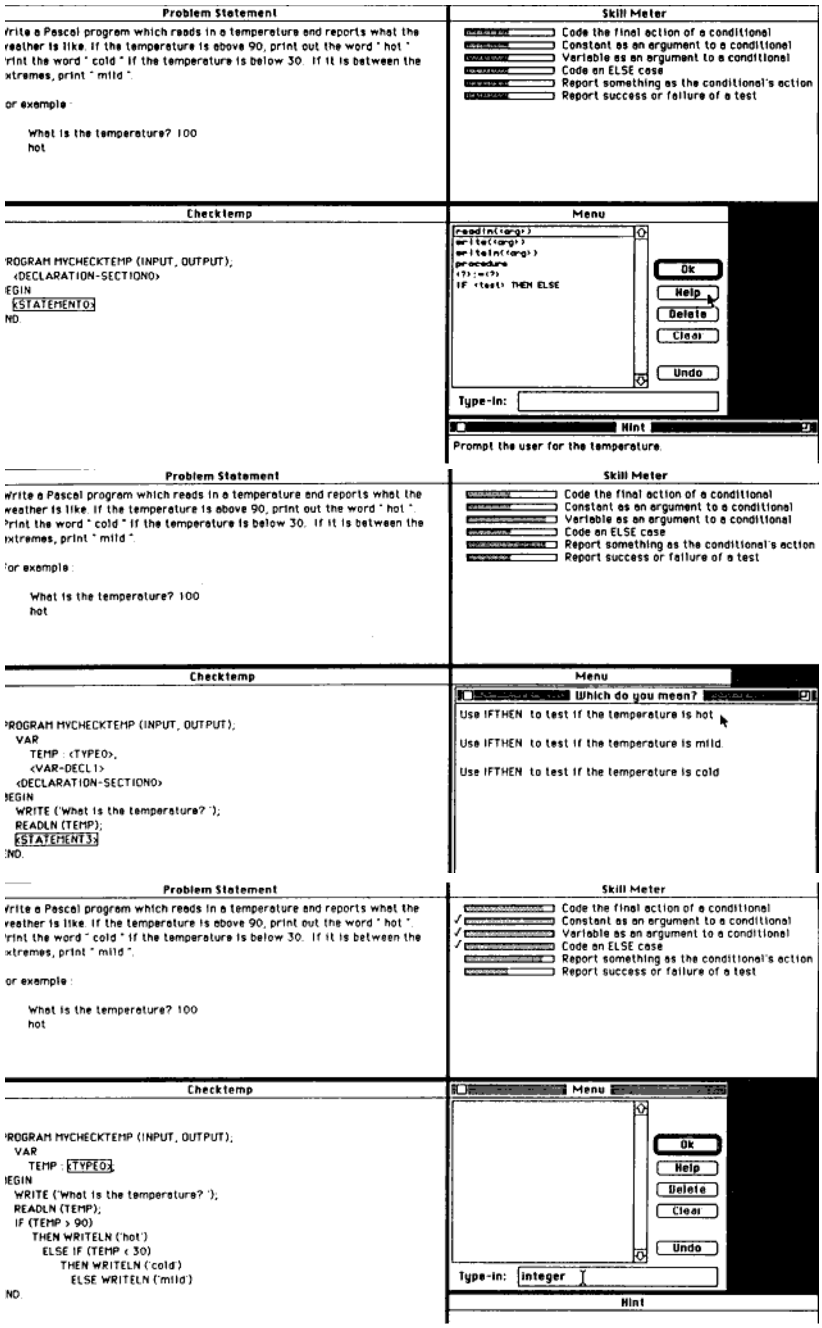


FIG. 6
Pascal-Tutor
Anderson (1993).

The four screens demonstrate the course of a session with Pascal Tutor.

Top left is the task window, top right you can see a progress indicator, at centre right resources can be loaded, at bottom right there are occasional comments, and the student writes his program at the bottom left



Merrill

Merrill's »Component Display Theory« [Merrill (1983)] takes its foundations from the model of Gagné [Merrill, Li et al (1990a), 9; Snelbecker (1983), 464].

With the Component Display Theory (CDT), Merrill tries to make up for the level of operationalization which Gagné's model lacks, and to make instruction decisions directly deductible. Like Gagné's classification, CDT is also geared to instruction in general, and not restricted to computer aided instruction. Merrill (1987) applies his approach to computer aided learning in particular, and has since spoken of 'Second Generation Instructional Design', or ID2 [Merrill, Li et al (1990b)].

Component Display Theory

CDT separates subject matter and performance. CDT recognizes four cognitive components of learning matter: facts, concepts, procedures, and principles. CDT does not aim at a sequencing of the instruction process, as Gagné does, but distinguishes four forms of instructional actions, which Merrill calls »presentation forms«: *Primary presentation forms*, *secondary presentation forms*, *process displays*, and *procedural displays*. Among the primary presentation forms, Merrill counts teaching through *presentation of rules*, *examples*, by *repetition* and through *practice*. Occasionally, Merrill uses the term *transaction* (more of that later on), which is however often used synonymously with the term *presentation form*. The intention remains the same: either automate instruction decisions, have the authoring program choose transactions by itself, or have it suggest them to the author.

Further subdivisions make the taxonomy of CDT more extensive than that of Gagné. CDT forms a two-dimensional classification matrix of subject matter and performance, based on correspondence rules for the relation between teaching methods and objectives, which distinguishes the following categories: find, use, remember versus fact, concept, procedure, principle. CDT also offers a two-dimensional matrix of primary presentation forms with the following subdivision: tell or expository, question or inquisitory versus generality, instance. Finally, there is a matrix of secondary presentation forms with the following subdivision: primary presentation forms versus type of elaboration (context, prerequisite, mnemonic, mathemagenic help, representation, feedback). The instructional core is made up of a set of prescriptions for relating objectives and methods. Despite the many curious terms and classifications, the Component Display Theory leads us into shallow waters, intellectually speaking [Stone in a criticism of Merrill (1987b), 10].

ID Expert

Merrill demonstrates how the system is meant to function in practice with the program *ID Expert*, developed for the Army Research Institute, which is supposed to automatically generate instruction decisions. *ID Expert 1.0* was realized on a Vax, and *ID Expert 2.0* on a Macintosh with *Nexpert* and *HyperCard*. The program starts with a task analysis, and represents knowledge in separate frames for subject matter, course organization, strategies, and transactions. Transactions are described by Merrill and Li (1989) in a matrix of **functions** (*Overview*, *Presentation new*, *Remediation (old)*, *Practice (early)*, *Practice (late)*, *Review*, *Assess/dlg.*) and **transaction types** (*Synthesis*, *Summary*, *Exposition*, *Conversational Tutorial*, *Compare* and *Contrast*, *Edit*), with each cell assigned a »certainty factor« between +1.0 and -1.0. In other words: *ID Expert* chooses the different instruction methods for instruction units according to pre-set probability factors. In the first version, the number of dialogues by way of which *ID Expert* questioned the designer to obtain the necessary knowledge was criticized [Jones (1992)]: »However, in a second implementation, using Nexpert and HyperCard on a Macintosh, some of the overwhelming detail exhibited within the first has disappeared« (10).

The relations between realms of objectives, forms of behaviour, and presentation forms are meant prescriptively. They are basically made up of a classification of pragmatic theorems born from experience. CDT must be denied any theory status. Merrill seems to be consciously guarding himself against a critical objection of that kind when he says: »Component Display Theory (CDT) is not a method but rather a theory about those components that comprise every instructional presentation« [Merrill (1988c), 61]. One must object here that the result of CDT are instructions for action in matrix form, and not a theory. Why should a prescriptively meant decision matrix lend CDT the status of a theory? This example demonstrates what I will have to point out several more times in a further description of instructional design, namely how thoughtlessly the term of „theory" is applied in research.

Reigeluth

Reigeluth (1979) describes learning systems – also modelled on Gagné – by way of instruction objectives, conditions of instruction, and methods of instruction. Among the latter, he also counts strategies of learner control [Chung/ Reigeluth (1992)]. Reigeluth (1992) distinguishes between descriptive theories of learning and prescriptive theories of instruction. The latter, so he claims, pay more attention to the generic abilities, abilities of reasoning and problem-solving, learning strategies, and metacognition.

Elaboration Theory

Reigeluth and Stein (1983) try to expand Merrill's CDT to a macro level with the Elaboration Theory. For the micro level of designing lesser instruction units, they refer to Merrill's CDT. The Elaboration Theory distinguishes between concepts, principles, and procedures. Basically, the model consists of a description of the so-called zoom lens effect, an expansion of Merrill's elaboration mode, or, as Snelbecker (1983) thinks, an extension of the epitome, of Ausubel's »advanced organizer« (467). The zoom lens effect describes the progression from the simple to the complex, starting with the epitome and progressing with the expansion of that condensed idea, with the process differentiated according to the three levels of learning objectives: concept, principles, and procedure. The elaboration theory is a didactic methodical metaphor, which one might call zoom principle, or magnifying glass view, macro overview and micro insight, fading in and out, centring and decentring etc., that is, it is basically a simple methodical recipe, which however becomes relatively complex in the end through the differentiations. Nevertheless, if I might be permitted the pun: Proclaiming the zoom lens effect and elaboration a theory turns the epitome into an epitaph.

Reigeluth acts as a synthesizer in the field of diverging theories of instruction, as the attempt at a synthesis of the proponents of instructional design with his conference of 1983 proves, which I will discuss below in greater detail. Reigeluth (1992) stresses the importance of instruction theory, which he says is always being overlooked by ITS approaches (52). As types of learning, he stresses: »(1) memorizing information, (2) understanding relationships, (3) applying skills, and (4) applying generic skills« (54). He tries to break through to a synthesis of the existing approaches, and compares the taxonomies of Bloom, Ausubel, Merrill and Gagné, without however getting any further than stating vague similarities, because the methodological character of the categories does not allow anything more:

TAB. 1 Taxonomies of Bloom, Ausubel, Gagné and Merrill

Bloom	**Ausubel**	**Gagné**	**Merrill**
knowledge	rote learning	verbal information	remember verbatim
comprehension	meaningful verbal learning	verbal information (2)	remember paraphrased
application		intellectual skills	use-a-generality
analysis synthesis evaluation		cognitive strategies	find-a-generality

Reigeluth imagines the realization of instruction systems as an expert system in the ideal case, although he has to admit: »But our knowledge database is woefully inadequate in this area«. The use of expert systems does not have to fail because of the knowledge base in my opinion, it rather fails because of the state of instruction theory, which because of its origins cannot fulfil one of the methodological prerequisites of expert systems, namely that they must put their instructional prescriptions in the form of if-then statements.

Attempt at a Synthesis

Reigeluth made the attempt with a conference in 1983 to document the ID systems existing up to then (Gagné, Scandura, Landa, Merrill, Reigeluth) [Reigeluth (1983)]. In his summarizing article, Snelbecker (1983) examines the historical perspective which the instructionalists taking part in this conference expected: »Phase I would involve presentations of new principles, theories, statements about instruction. Phase II would involve comparing current ideas and trying to see how available theories compare and contrast with each other. It would appear that in instructional psychology–as well as in other sectors of social-science theory construction–we invest all of our time in Phase I and almost ignore Phase II« (455). Reigeluth comments here that the transition to Phase II was the purpose of the conference. Five years later, several contributions are published simultaneously trying to bring together instruction theories with IT systems, which need an instructional component in their student and tutor models [Park/Seidel (1987); Merrill (1988a); Scandura (1988); Tennyson/Rasch (1988)]. A comparison of the volumes by Reigeluth (1983) and Jonassen

(1988a) is interesting. Five years after Reigeluth, Jonassen makes a similar attempt as Reigeluth in his reader, but with the difference that this volume, apart from the approaches of Gagné and Merrill from the field of instructional design, already contains approaches of the kind that strive for an integration of individual learner strategies (Jonassen) and intelligent tutorial systems (Tennyson, Mackay, Kearsley) [Keller is again allowed to bring up the rear with his motivation psychology in this volume].

In 1991, a debate of the instructionalists with the constructivists takes place in the journal *Educational Technology*, going on for several numbers, which in view of the clearly noticeable emotional state of Merrill and Reigeluth gives the impression of a »last stand« (I am going to come back to this at the end of this chapter). Since then, hardly anything has been heard of instructionalism, although Reigeluth (1992) states even in 1992: »and hopefully we will see much progress over the next decade«. I cannot help the impression that all contributions on instructional design that have been published after 1988 have not brought anything new. Merrill's articles, for example, are merely replicas of earlier work, whose repetition seems like an attempt at marketing in order to make this approach popular. The conference proceedings published since then, e.g. that edited by Scanlon and O'Shea (1992), always combine approaches from various fields. Instructionalism seems to be outdated, its success in teaching practice, according to the statement of VanLehn (1992), who worked in the field himself, did not come about: »Although such work has profoundly changed our image of competence and intelligence, and that change has begun to seep into the educational system, it is fairly clear now that the resulting programs/theories have not had as much direct effect on education and training as could be desired« (24). Three factors put the screws on instructional design: one, IT systems, whose proponents, like J.S. Brown and Clancey, supported partially constructivist postulates after 1988, two, the constructivists, who since Papert (1980) had been experimenting with the micro world approach, and were reflecting on situated cognition and designing social communicative learning environments since Rogoff and Lave (1984), and three, the popularity of hypermedia systems, whose potential was demonstrated so spectacularly since 1987 by *Athena*, *Intermedia* and *HyperCard*, and which today largely dominate the commercial market and international networks.

Further Development of Instruction Theory (ID2)

Merrill, Li et al (1990a) criticize the inadequacies of first generation instructional design (ID1) and coin the term »Second Generation Instructional Design« (ID2). They criticize the following shortcomings of first generation instructional design [s.a. Merrill, Li et al (1990b)]:

- ID1 concentrates on isolated skill components and does not know any dynamic, complex units
- ID1 has only limited prescriptions for knowledge acquisition
- ID1 has only limited prescriptions for course organization
- ID1 theories are closed systems
- ID1 does not integrate instruction phases
- ID1 only teaches scraps, not an integrated whole
- ID1 is often passive and not interactive
- ID1 presentations are constructed on the basis of small components
- ID1 is too labour-intensive.

With this catalogue, Merrill, Li et al have indeed taken up many points which had been criticized about instructional design, the poor complexity of objectives, its passive model of learning, the progression from small objectives to larger objectives without however giving up the approach of instruction as such with its prescriptions. As a modification, they propose ID2 [Merrill, Li et al (1991); Merrill, Li et al (1992)], second generation instructional design, which is supposed to have components which, with the help of a knowledge base, the employment of expert systems, and a tutor, translate learning objectives directly into instruction methods in order to achieve the intended saving of labour:

- A database with theoretical knowledge on instructional design
- A method for the presentation of the knowledge base, the Knowledge Acquisition and Analysis System (KAAS)
- A collection of mini expert systems
- A library of transactions for instruction, the Transaction Library and Transaction Configuration System (TCS)
- An intelligent advisor, which works in a dynamic dialogue mode with alternating/variable initiative (IADV)
- And five other tools.

Transactions

In expanding the approach, Merrill develops the method of instructional transactions [Merrill, Li et al (1992)]. Transactions are instructional algorithms of objective-method interactions, which are more complex than the simple interactions of Programmed Instruction [Merrill (1991), 50]. While in ID1 the term presentation was dominant, ID2 makes transaction its central term. A presentation in ID1 is the procedure which translates the instructional prescriptions into screens. ID2 has a wider area of influence, it is not limited to learning programs but aims at being a general theory of instruction. A transaction is a particular form of interaction with the learner, it is characterized by a mutual dynamic exchange between the instruction system and the learner. The Transaction Theory [Merrill, Li et al (1990c)] describes transaction as a »particular instructional interaction with a student. A transaction is characterized as a mutual, dynamic, real-time give-and-take between the instructional system and the student in which there is an exchange of information. Transactions include the entire range of instructional interactions including: one-way transmission of information (e.g. video, lecture, or document, which are not very good transactions because they lack interaction), discussions […]« (9). Despite the verbosity, this is a typical instance of definitions which seem plausible but are actually under-defined. Jasper's (1991) comment points out the misuse to which Merrill puts the term interaction: »There is an inconsistency here that cannot be overlooked. We sense the AECT- and the Gagné-type of thinking behind this interaction-talk. It is still the teacher who is in focus« (21ff.).

A transaction class is an element of a transaction shell. Transaction sets are transaction shells which are similar. A transaction contains a »mental« model and a learning activity assigned to that model, which together are called an »enterprise« (17ff.). Complex processes like driving a car, using a spreadsheet etc. are enterprises. Merrill, Li and Jones distinguish the following classes of transactions (22ff.): Component transactions (3 frames and 3 transactions): *identify for entity frames, execute for activity frames, interpret for process frames*, Abstraction transactions (5 classes): *judge, classify, decide, generalize, transfer*), Association transactions (5 classes): *propagate, analogize, substitute, design, discover*. Using the example of a training program for aircraft maintenance, possible enterprises and the respective mental models are listed. All transactions must be able to employ the following methods: selection of knowledge, knowledge sequencing, instruction management, and instruction output (20).

In my opinion, ID2, which Merrill calls transaction theory, cannot claim the status of a theory. ID2 is rather a method: transactions are complex methods combining knowledge, skills, and interaction opportunities. A transaction shell consists of an authoring environment and a runtime environment, just like in authoring systems. The authoring environment consists of a knowledge acquisition system and a configuration system for transactions. The system thus seems to be suited to the development of courseware [Li/Merrill (1990)]. The knowledge acquisition system makes use of an expert for the technical contents and stores its knowledge in a knowledge base. The configuration system for transactions has parameters with the help of which the type of interaction can be controlled.

Is »second generation instructional design« really something new? Is it, as Weidenmann (1993) supposes, »a kind of synthesis«, »a pragmatic middle position« (12) between instructional design and constructivism? ID2's aim, according to Merrill, is, among other things, the integration of the constructivist approach with a simultaneous rejection of allegedly »radical« constructivist consequences [Merrill, Li et al (1990c); Merrill (1991)]. I come to a different conclusion from Weidenmann's: Merrill reinterprets the constructivist concepts and distorts them beyond recognition. At the same time, he holds to instructional design, the prescription of methods from objectives, at the core. The learning objectives remain objectivistic and reductionist. He is still concerned with the acquisition of a »certain kind of knowledge or skill«. The context dependency of learning is only added to the surface of the learning program, any claim to the term of »situated cognition« has the status of word problems in mathematics. As before, there is no room for understanding and interpretation in ID2.

Lack of Success

ID systems have not been able to gain acceptance in practical use up to now. Dick (1991), in reaction to criticism of the poor state of the education system in the USA, admits that ID has not gained access to the schools: »It should be noted that instructional designers cannot be blamed for poor student performance because designers have had almost no part in shaping the American public school curriculum! Nearly all advances made by designers, aside from those carrying computers, have been rejected by the schools over the last 20 years« (43). It seems somewhat one-sided to lay the entire blame for the state of ID on the schools. The reasons for the lack of success are probably not to be found in the high cost of ID systems either, as some writers assume, but in the structure of the approach itself. ID systems are not as flexible as courseware because of their dependence on the objectives-methods matrix. They are extremely limited in design. Locatis and Park (1992) also doubt the efficiency of the automatic construction of learning units in instructional design. Conventional CBT authoring systems do not seem so bad to them in comparison, as instructionalists always claimed. Gloor (1990) thinks that the immaturity of ID systems themselves is responsible for the low grade of acceptance: »The concepts to be realized in such systems are much too complex to have been completely understood let alone realized up to now. Even a system like IDE only represents a first step in that direction. Considering the current state of knowledge, it will be at least five to ten years until the advent of more mature systems« (225).

Examples from Instructional Design

The starting point of instructional design is criticism of the rigid structure of Programmed Instruction: »Most CBT authoring systems have a frame-based architecture«, Li and Merrill (1990) criticize in comparing the architecture of non-instructional programs based on algorithms [s.a. Merrill, Li et al (1991)]. They want to arrive at systems which separate the instructional part of the program from the subject matter and are variable in the choice of presentation methods. In this way, one could more easily change and modify the subject matter of a learning program, without having to change the construction of the program as a whole. The next step is represented by programs which do not store tasks but generate them ad hoc [Park/Perez et al (1987)]. At first, a random generator was used, then AI techniques later on. The implementation of Merrill's Component Display Theory took place in the authoring system TICCIT [Merrill (1980); Merrill (1988c)]. Merrill illustrates his remarks on CDT with some screens generated by TICCIT. I am reproducing some screens from »English Grammar« (redrawn after the originals), in order to demonstrate to the reader what the result of generators in instructional design looks like, and why my criticism turns out to be so harsh [s.a. Merrill (1983); Merrill (1987); the typing mistakes in the screen dumps are not mine].

FIG. 7 Rule Explanation in TICCIT, Ill. after Merrill (1980)

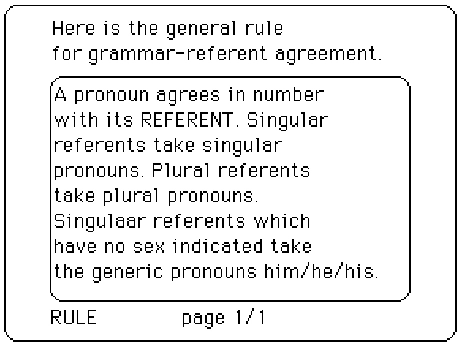
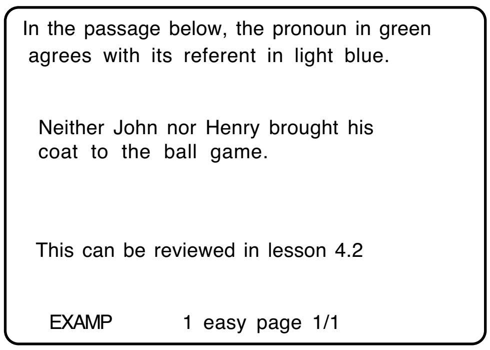
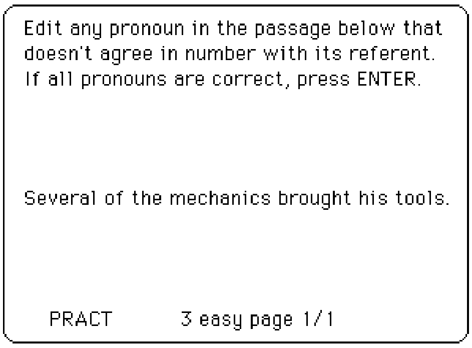


FIG. 8 Example from TICCIT, Ill. after Merrill (1980)



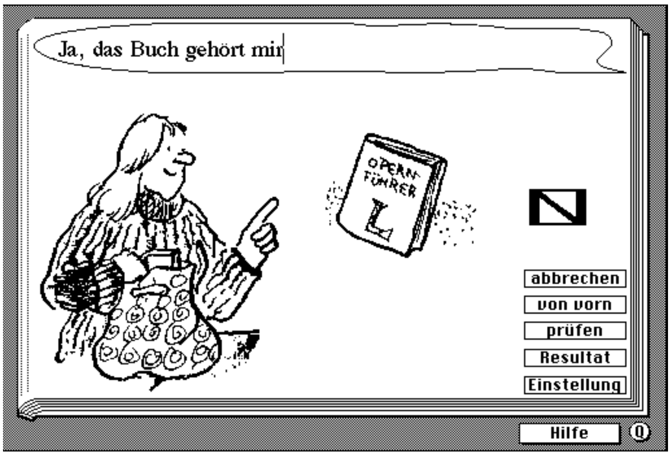
What distinguishes the illustrations from TICCIT from Programmed Instruction cannot be judged on the illustrations alone: The first illustration presents the explanation of a rule, the second illustration shows an example, and the third an exercise. All three screens show only text and rely exclusively on a question-and-answer matrix and the page-turning mechanism. It is how these 'presentation frames' were generated that makes the difference from Programmed Instruction, although in my opinion it is more important how they are presented to the learners, because the difference from Programmed Instruction does not matter from their point of view (or perhaps just a little because of the abstention from multiple-choice questions).

FIG. 9
Exercise from TICCIT, Ill. after Merrill (1980)



In comparison, I am showing an exercise form a language learning program by Grießhaber (1992), which presents pictures, invites the learner to produce sentences for these pictures, uses a microphone as input source, and checks the sentences thus entered for correctness.

FIG. 10
Program by Grießhaber (1992)



The program *Algebra* , which was also developed in TICCIT, possesses a somewhat more sophisticated screen design. But *Algebra* is still designed using the same learning pattern.

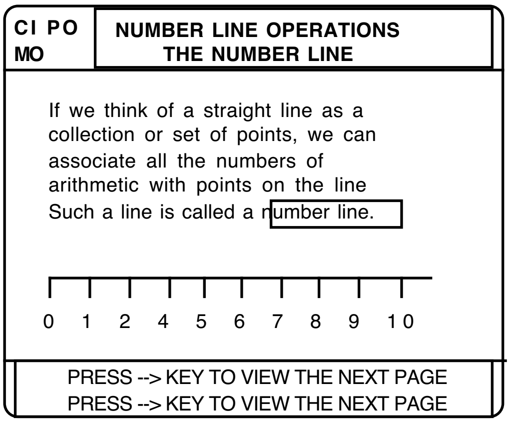


FIG. 11 Screen from *Algebra*

By way of comparison, two illustrations from *Mathematical MacTutor* by the University of St. Andrews, Fife, in Scotland, a tutorial on algebra, analysis and geometry which is based on the concept of discovery learning. *Mathematical MacTutor* offers unusual exercises, whose mathematical content can often not be divined at a first glance, because they are tricky riddles: Escher images, tangram figures, chess problems, and several editors for three-dimensional bodies. The student is supposed to explore the tasks. In addition, Mathematical MacTutor offers historical excurses on the historical background of the problems presented.

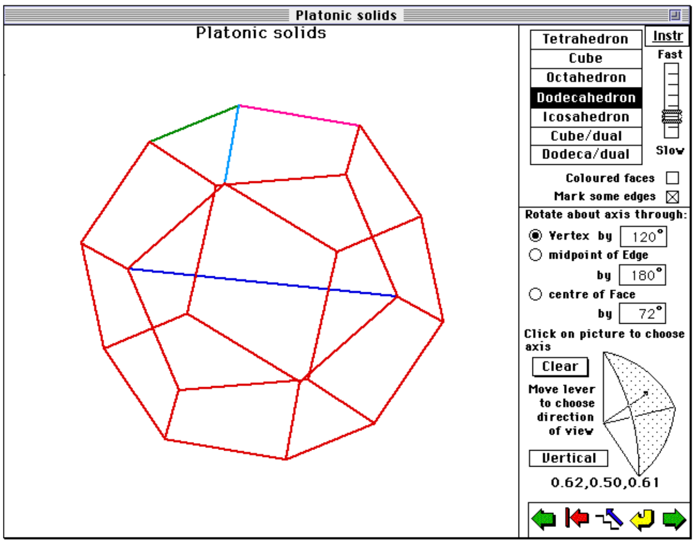


FIG. 12 Three-Dimensional Bodies from *Mathematical MacTutor*

The two- and three-dimensional bodies in *Mathematical MacTutor* can be manipulated with the help of the tools to the right of the illustration, or directly. Values, parameters, and diagrams are bidirectionally interactive. The program is therefore ideally suited to discovery learning.

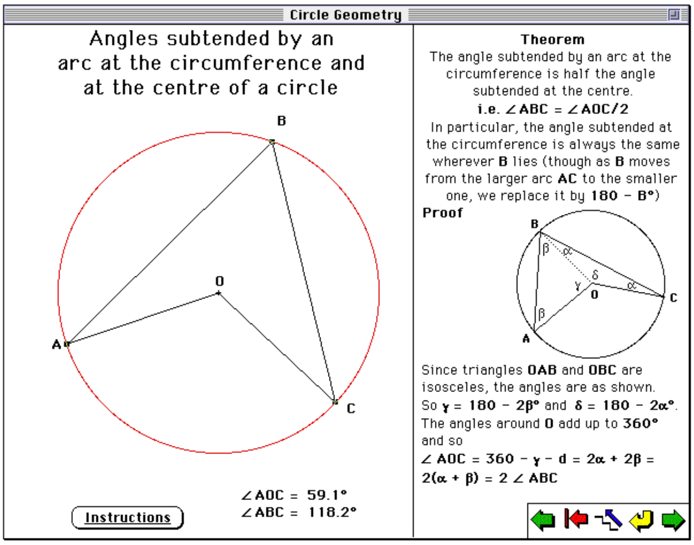


FIG. 13 Triangles in a Circle: Exercise from *MacTutor*

Finally, two illustrations from the program *Poetic Meter* by Merrill.

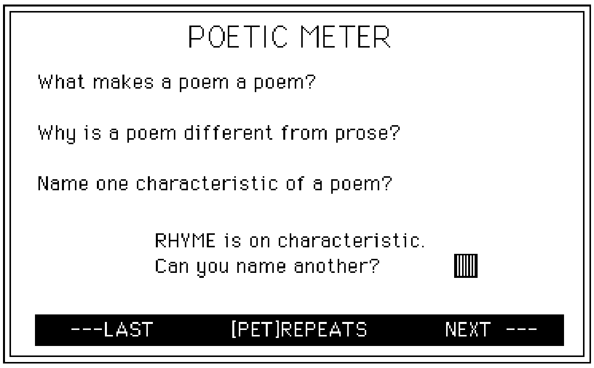
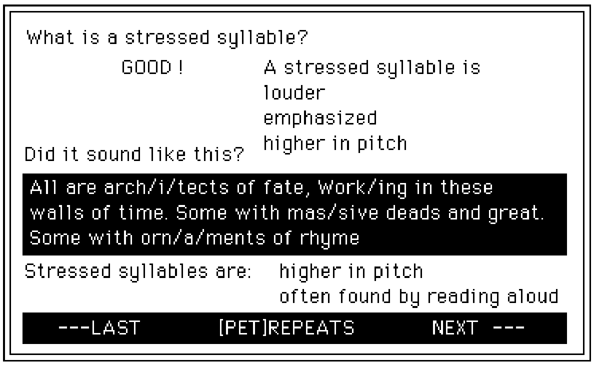


FIG. 14 *Poetic Meter* by Merrill

Fig. 15
Poetic Meter
by Merrill



Worth mentioning here – apart from the display in inverted typeface – is that the program uses sound output (Merrill calls this »sound reinforced example«). Even here, the mechanism of question and answer for each screen can be seen clearly. The lines appear one after the other and represent didactical steps in the program. The word »GOOD !« only appears after a correct answer. I cannot see for the life of me what is supposed to distinguish this form of didactic differentiation from the behaviourist model of learning through reinforcement as far as the educational consequences are concerned.

Merrill gives further examples, such as a natural science program with laboratory instruments displayed in silhouette. But the graphics are still not interactive here, the question-and-answer mechanism remains the same, with answers only possible by pressing a key. Towards the end of his presentation, Merrill employs completely different programs in order to intimate that instruction with interactive graphics is a desirable aim: the *Pinball Construction Set* by Bill Budge, and a laboratory construction set, a predecessor of *LabView*. But Merrill is leaving his own base in instructional design here, and moving on to the area of highly interactive, object-oriented software. These programs use only direct manipulation, no question-and-answer mechanisms, they invite constructions which are not limited to presentation frames or transactions, and they contain »intelligence« only in the sense that they know how the laboratory modules constructed by the user work, but not in the sense of automatically »instructing« the user out of a library of transactions. I cannot imagine a way for Merrill to progress from his programs to these highly interactive construction programs without abandoning the foundations of instructional design, and I wonder why he cites them.

IDE (Instructional Design Environment)

IDE by XeroxPARC came into being as an extension of *NoteCards* [Russell/Moran et al (1988)]: IDE as an authoring system contains components for course design, course development, course adaptation. Problem constraints can be entered. The designer is called Subject Matter Expert (SME) in IDE. The lessons consist of a knowledge base and instruction units. After design, IDE offers two instruments for analysis: Tracer and Checker. The units (Instructional Units) consist of three different sets of rules which work together: strategy rules, educational rules and tactics rules. IDE turns over the knowledge base, instruction rules and instruction units to the IDE interpreter. The IDE Interpreter is made up of four components: the instructional problem-solver, a program for the selection of instruction units, a program for applying the instruction units, and a program for updating the student model (MOS-Updater). IDE uses three knowledge bases: knowledge structure, a list on student history, and the student model (MOS). Russell's (1988) article on IDE is especially interesting, because he quotes some of the rules and the specification language of the IDE interpreter in plain English [s.a. Pirolli/Russell (1990); Gloor (1990), 218ff.].

MAIS (Minnesota Adaptive Instructional System)

MAIS, the Minnesota Adaptive Instructional System [Tennyson/Christensen (1988); Tennyson (1993)] aims at an expansion of instructional design in two aspects: Tennyson wants learning objectives of a higher value, he wants to integrate the learning methods needed for that, and wants to establish a direct correspondence between learning methods and learning theories for this purpose. Tennyson distinguishes not only declarative knowledge and procedural skills, but also contextual knowledge, cognitive strategies, and creative processes. He wants to provide corresponding learning methods (simulations, case studies, and cooperative learning), and he wants to establish a direct link between theories of learning and instruction, with theories of learning meaning the cognitive complexity hypothesis and constructivism. This hybrid approach does not of course exempt Tennyson from the accusation of eclecticism that was brought forward against the instruction models, on the contrary, if you take a closer look at the functionalist transformation of objectives which constructivist ideas experience in being integrated into such a system, one can only speak of exploitation, hardly of integration. MAIS already has a component which monitors the learning behaviour of the student, and a tutorial model reacting to this. MAIS, as an adaptive authoring system, is therefore listed in the grey area between CAI and Intelligent Tutorial Systems by Wenger [1987, 12].

IDioM

The IDioM-System [Gustafson/Reeves (1990)] developed in *HyperCard* distinguishes seven functions (analysis, design, development, evaluation, implementation, production, management) and corresponding activities.

AIDA

Die U.S. Army has been quite active in the area of instructional design as well [Perez/Gregory et al (1993)]. Muraida and Spector (1992) discuss conclusions drawn from the US Air Force's AIDA Project (Advanced Instructional Design Advisor), which made the automatic design of technical training materials its objective. AIDA employs instructional strategies which can be varied in several dimensions, e.g. degree of learner control, degree of qualitative feedback in practice phases.

ISAAC

McAleese and Ching (1993) introduce ISAAC, an advisor based on the Gagné-Briggs model of instruction.

The applications that seem especially absurd to me are those that were developed with the help of instructional design and whose subject matter again is instructional design, so that they are dealing with themselves, so to speak, e.g. the program by Cook and Kazlauskas (1993), who want to develop production guidelines for computer aided training, and the program *IByD* by Urdan, Blumenfeld et al (1992), a system that is supposed to instruct in instructional design by way of instructional design.

Winn (1987) distinguishes the ID approaches according to their degree of adaptivity:

- Systems which do not have any adaptive structures. The objective-method relation is firmly implemented in them, branching occurs at predetermined places and solutions;
- Systems which do not only contain predetermined solutions (objective-method relation), but can also choose strategies on the basis of their own instructional principles and form production rules from them;
- Systems which are able to adapt their rules of production, which are capable of learning in a way (66ff.).

According to Winn, the systems without adaptive mechanisms show a »relatively low level of sophistication, where often only the difficulty of problems is varied […] the outcomes of instructional decisions made by the system are branched to parts of the program that act in pre-determined ways« (66). Prerequisite for the systems with modifiable production rules is that the expert's expertise is built into the program.

Wilson and Cole (1991) compare nine programs on instruction design which differ in the emphasis on problem-solving vs. skill training, detailed vs. broad cognitive task analysis, learner control vs. program control, and mistake-restricting vs. mistake-propelled instruction. Wilson and Jonassen (1990/91) compare 18 ID systems and try to classify them according to the design model they are following: ID environments which work like CAD/CAM tools, expert systems which act as advisors, CASE-Tools which generate ready-made code for the application, and hybrid models.

An overview of the programs actually realized with the means of instructional design leaves a disappointing impression. The programs are negatively characterized by meagre scope in learning objectives, small variance in method, and rigid instructional designs. If one looks at the continuously iterated examples from the area of small cognition, one starts to wonder where the advertised »dramatic increase in the sophistication of computer-based expertise and diagnostic capabilities« [Lepper/Chabay (1988), 243] has gone.

Should I be content with developing teaching materials with which allow me to learn how to connect a battery to a light bulb [Psillos/Koumaras (1992)], to practise borrowing (from the left) in subtraction [VanLehn (1988)], push discs with variable force [Plötzner/Spada (1992)], hang weights on threads without mass, let points wander in the microworld of a system of coordinates [White/Horwitz (1990)], solve the problem of which path a sphere will take after leaving a spiral, which way two boats will take crossing a river with changing current, or which path a ball will follow if thrown off a cliff [White (1992)], to navigate PacMan through a labyrinth, or arrange Mrs. Fisher's furniture correctly according to instruction [de Corte/Verschaffel et al (1992)], solve the well-known problem of choice of media [Seel (1992)], play around with 60 exercises on the superposition of two movements [Mandl/Bollwahn et al (1990)], display speed and direction of movement in a graph [diSessa (1992)], work on programming problems in LISP [Linn/Katz et al (1992)], or even formulate BASIC Statements of LET X = A quality [Mayer (1992)]?

I agree wholeheartedly with the conclusion of Cohen (1985):

- »The resulting programs are frequently boring intellectual exercises of the designers, and lack the motivational force of good classroom instruction« (33).
- »Few programs fully utilize the new technologies' capabilities, and most programs do not come close to emulating a personalized, interactive, dynamic educational experience« (36).

The Methodology of Instruction

Instructional design (ID) considers itself among the cognitivist theories: but it is clearly evident that the conceptual model as a rule only includes classification schemata for objects after the pattern of biological taxonomies, with additional causal, probabilistic or correlative connections between actions, and does not include cognitive concepts in the sense of cognitive psychology. According to Reigeluth, the goal of instructional design is to define concepts and establish principles. Their concepts, after Reigeluth, are classification schemata organized in levels of inclusion, often hierarchically and in the shape of tree diagrams. Such classifications are often arbitrary, they characterize phenomena in many alternative ways, and show varying degrees of predictive usefulness.

The use of Bloom's, Gagné's and Ausubel's classifications in almost all instructional design approaches makes it clear to the methodologically interested that the value of the categories and differentiations is rather heuristic than explanatory. »Most current 'instructional theories' consist largely of taxonomies and techniques« [Scandura (1983), 217]. Strictly speaking, as was the case with Bloom's list of learning objectives or Gagné's list of learning conditions, it is not even a case of taxonomies, but collections of terminological codes, lists whose categories may overlap and are neither equally scaled nor exhaustive. The categories' origin is arbitrary in itself and is seldom theoretically justified. As Scandura emphasizes, they are »subject matter characteristics«. Instructional goals cannot really be anything else by definition, because the concepts they refer to grow out of classifications of the subject matter according to principles of material logic or inherently scientific differentiations of subject matter, instead of being won from an analysis of the learners' cognitive concepts.

Prediction and Methodology Status

ID includes information on learning methods, learning conditions and learning results, which are classified on a global level according to effectiveness, efficiency, and attractiveness. By conditions of learning, they understand the factors or variables which influence the chosen methods' efficiency. The goal of instruction theory consists in the creation of classifications with a high degree of predictive usefulness. Prediction over and over again serves as the instructionalists' decisive argument why classifications should be regarded as a theory. Reigeluth (1983b), for example, calls the triad of »conditions, methods, outcome« a theory because ID aims at statements about the functional structure (21). Instructionalists declare their classifications to be implicit statements about the effectiveness of the methods behind them with regard to certain learning objectives. Instructional design is primarily interested in suggesting optimal methods for the achievement of certain learning objectives. »ID theories are thus prescriptive and pragmatic and, not surprisingly, show an eclectic character« [van Berkum/de Jong (1991), 323]. Such a characterization makes the methodological status of instructional design seem problematic, as a reflective proponent of instructionalism like Scandura (1983) freely admits: »In most cases, they only minimally satisfy the requirements of good theory, completeness, cohesiveness, parsimony, precision, and operationality« (217). Most instructionalists, however, tend to assign a higher value to their classifications.

Descriptive theories also formulate functional relations, but they do it on the basis of observed data, as generalizations of observations. In their case, the distance toward the rationalistic model of a theory as a set of law statements is not as great. The problem of subjectivity is less evident as well. In ID systems, the decision-making process plays a part [Seel (1992)]. Seel criticizes the quality of ID systems because they are not able to produce prescriptions on the basis of decision theory in a rational way. He does not go as far, however, as to put down this deficit to the methodological problem that one cannot theorize practical decisions from prescriptive premises, because he wants to make instructional design immune to arbitrary decisions by way of a foundation in decision theory: »Merrill's expert system and the IDE of Russel et al. do work, but with regard to decision-making as a process of problem solving they lack a comprehensive and generalizable basis for decision theory. One way to improve this situation is to use the prescriptive decision theory (PDT)« (65). He chooses the classic topic of media selection for an example (76ff), one of the few examples in which the decision-making problem can be demonstrated in full. If instructionalism could meet Seel's demands, it would have to be awarded a place in the tradition of analytical science which has been called the rationalistic tradition by Winograd and Flores [(1987), 14ff], if the impossibility of theorizing practical decisions which has already been mentioned did not stand in the way of such a classification.

Theories of learning are descriptive by definition, theories of instruction are prescriptive by definition. As a rule it can be said that the propositions of a descriptive theory cannot be turned into prescriptive propositions [Habermas

(1970), 24]. Non-prescriptive instructional design would not make any sense: »Instructional theory MUST be prescriptive« [Scandura (1983), 216; cf. Landa (1983a)]. Scandura reserves the characteristic „explanatory“ for descriptive approaches, and for himself dismisses any claim of wanting to develop a theory: »Indeed, the Structural Learning Theory is not really a theory at all«. Reigeluth seems to be conscious of this argument when he comments defensively on the theory problem: »People also use the term theory in different ways. But an instructional-design theory […] is usually thought of as a set of principles that are systematically integrated and are means to explain and predict instructional phenomena« (21). Is such a classification as a »set of principles that are systematically integrated« enough to justify a claim to theory status?

According to Reigeluth, instructional theories are supposed to explain and predict. But what are they supposed to explain? Paradoxically, they are to explain the effect prescribed by themselves! The efficiency statements which instructional theory aims at do not have any explanatory potential. Methods and conditions are means to an end, efficiency statements consist of simple means-to-end relations, and instructional design mostly stresses the systematics of efficiency statements. This becomes especially clear in the end-means-matrix which Merrill calls »transaction theory«, which cannot even claim a status of functionality. Reigeluth (1983b) knows that the efficiency statements are not deterministic. He calls the relation between instructional prescriptions and learning effects probabilistic. All the same, he apparently wants to assign a methodological status to them which resembles that of prognoses in physics. Winn (1990) has pointed out that this characterization contains a validity problem. If the relations between prescriptions are not valid, instruction turns into experiment: »Without the validity, making decisions about instructional methods would have to rely on trial and error, which Merrill (1975) has pointed out is not an efficient way to do instructional design« (64).

Descriptive, Nomologial and Prescriptive Knowledge

Landa (1983a) differentiates propositions in descriptive theories of the if-then form from propositions in prescriptive theories which take the form »in order to …, do this«. And he makes clear that the latter cannot be created from if-then rules by transformation (60). The problem becomes particularly evident through the distinction between algorithmical and heuristic rules which Landa introduces (58). Instructions of the kind »search for an analogous problem« or »try to break down the problem into smaller problems« are heuristic instructions to the learner in the problem-solving process. They serve to help the learner, but they do not explain anything. But if heuristic instructions may occur in ID, then it is clear that ID has a low explanatory content. Even with if-then statements, instructionalists always hit upon methodological problems. For good reasons, almost all authors choose statements from physics by way of illustration. But even with this kind of knowledge, which lends itself to nomologization relatively well, they demonstrate problematic arguments: Is an if-then statement like »if water becomes hotter than 100° C, it turns into steam« a law or perhaps already a theory? In the first place, this phenomenon is an observation and the result of measuring. The observation only becomes a theory if I generalize such observations and formulate something like a theory of boiling-point. If one defined the »outcomes«, i.e. learning results, as the phenomena explained, there would be a tautological relation. I could just as easily claim that the police explain traffic with a traffic-flow theory by putting up »20 mph« signs, the explained phenomenon being the speed behaviour of the road-users. But these are merely obeying a simple instruction (or do not, as the case may be).

Deduction and Prescription

In a more narrow sense, a theory in epistemology means a deductive theory, a system of definitions and statements from whose premises and axioms one may deduce other statements. The aim of these deductive theories is to classify real phenomena, to explain relations, to enable hypotheses and to prognosticate effects. Their system of statements must meet the requirement of consistency. Explanation, prognosis and consistency are not possible in a strict sense in social sciences theories; there, theories only serve to describe and classify phenomena and communication about phenomena. »The social sciences are in a much worse position with respect to explanatory power than are the physical sciences« [Pylyshyn (1991), 40]. Nevertheless, prescriptive approaches are even weaker theoretically than social sciences theories. Other than the descriptive theories of social scientists which ascertain their subject with the help of empirical means, Reigeluth's prescriptive theory seems to me to jump this stage of theory development. Prescriptive approaches do not have any explanatory function any more, but only end-means relations which are reinterpreted as prescriptive functions, with the end-means relation not very marked in most instructional classifications. One can perhaps deduce from this that instructionalists would have preferred to have a functional theory at their disposal. Unfortunately, however, neither the kind of knowledge they deal with nor the construed cause-and-effect relation of prescription and learning result meet the requirements of such a scientific approach. Pylyshyn in this context mocks: »explanations of everyday naturally occurring events may have a character not unlike that of folk psychology« (41). Basically, such classifications are no theories but rather methods in the sense of more or less directly applicable statements of experience, or pragmatic instructions for acting. Their practical worth only appears when they have been accepted as collective interpretation patterns. This, however, could well prove to be their very problem, because they might turn into ideologies, as Pylyshyn stresses: »When 'theories' do tell you what to do – especially in the social sciences – you can be sure that it is for reasons other than their fundamental truth« (43). Instruction is about practice and practical decisions, not about explaining practice. Practical questions cannot, however, be decided by science, but are bound to a discourse about norms [Habermas (1970), 24].

Instruction as Program

In the »theoretical model« of ID, the instruction model starts with the definition of learning objectives. This is followed by a phase of selecting suitable methods. Lowyck and Elen (1992) point out that teachers and designers hardly follow this model in reality, that as a rule the designing process is informed by clusters of goals and methods, and that the first draft contains almost everything which is then refined, modified and revised in the subsequent process. ID does not see itself as a general normative theory of social interaction in teaching; the aim of the model is rather to deduct rules or algorithms of teaching. Instruction is a rule or program for the structuring of teaching [Landa (1983a), 57], with the qualification that there can be no relation of deduction between both ID and theories of learning and ID and learning programs or practice. Winn (1989) points out in addition that prescriptive cannot mean that the principles found by the descriptive »theory« could be turned seamlessly into instruction by way of prescription (41). The categories of ID aim at being on the one hand as general as possible, which would mean that they could no longer be made operational, and on the other hand as concrete as possible, which would lower the system down to an algorithmic level. VanLehn (1992) in this context speaks of an »unavoidable tradeoff between the generality of learning theories and their utility to educators« (24). On a methodological level, one can see the instructionalists' intention as the will to move towards a functional theory of instruction, but because they work with eclectic codes of terminology and methods, they only succeed in realizing a kind of pragmatic-normative program. Even if they succeeded in establishing prediction as a model of functionalism, the following would still hold: »Prognoses on the basis of empirical science about a usually to be expected co-variance of certain empirical quantities allow the choice of means for a given purpose to be rationalized. The purpose definition, on the other hand, relies on an assumption of norms and remains scientifically uncontrollable« [Habermas (1970), 24]. Functionalist and strategic action are merely borderline cases of communicative action, which is usually oriented towards the communicable meaning.

Ohlsson's (1992) statement can be interpreted in the spirit of a functional methodology: »The most stringent test of an instructional design is that it can be implemented on a computer. If the instructional design is clearly stated, then it should be programmable. If it is based on a learning theory and that theory is accurate, then the design should be sufficient to produce learning« (73). If the requirements to be met by instructional design are defined in such a way that the proof of their meeting the requirements lies in their ability to be programmed and tested, then there must be a misconception of what could be called a learning theory: There can be no theory of learning worth being called a theory of learning which at the same time lends itself to operationalization so easily that direct teaching decisions could be deducted from it. One should rather stick to the term instructional design, since ID is nothing more than a program or an outline for teaching.

There will always be a gap between a theory and its practical application, its transformation on a program level can never be a direct translation of the model, because »programs are not theories« [McCalla (1992a)]. Programs are one of several possibilities of realizing a model, they may be an indication, but not proof of the theory's functionality: »While they are precise and unambiguous, programs do not specify a semantics for the theory that they are encoding« (113). Since the programming languages in which the programs are written often do not posses a formal semantics themselves, »theories built on top of them are built on something akin to quicksand«. The deductive approach is violated in the concrete implementation, so to speak. This means that concrete instruction suggestions are no longer valid representations of general theories of learning. Strictly speaking one would have to say that the two levels are two different things. That is why VanLehn proposes »task specific theories« (26).

Explanation and Prognosis

All prescriptive approaches have this theory status dilemma. They set up a prescription, and if the learners follow the instruction, prescription turns into prognosis and category turns into explanation. But if a prescriptive theory is impossible, what is the alternative? I do not want to deny the value of instructional design's categorial schemata, nor of the instructions into some of which there has gone a lot of experience. It is just that their point cannot lie in being a theory and thus, as residual experience, to turn into ideology. They only gain a point through a communicative tie to social processes of reflection. If deduction is not to turn into decisionism, reflection must catch up with the relationship between decisions and norms, and this must be achieved by subjects who are themselves, through the act of reflection, part of the relationship they are reflecting [Habermas (1970)]. This dimension is missing completely in the instructionalism of, say, Merrill, whose decision-making tables and the »certainty factors« contained in them are not at all put up for discussion. Pylyshyn, too, stresses that his criticism is not aimed at the value or non-value of individual practical ideas, but at the methodological claim: »There is no denying that some people have important and valuable insights, both into human nature and into the design of technologies. But we should not confuse wisdom and insightfulness with having a scientific theory« (42). Winn (1989) goes one step farther and demands that the idea of instructional design as such should be dropped: »Indeed, the very idea that instruction can be designed in the first place must be abandoned unless one subscribes to the belief that how students will react to instruction can be predicted with reasonable accuracy. Instructional design thus construed depends on the learner being largely reactive to instruction, clearly a behavioral position« (40).

Methodology Claims

The methodological dilemma of instructional design becomes most evident in Jacobson and Spiro. Jacobson (1994) outlines a »framework« for fitting theories to design which he calls »Theory-To-Design Framework«. In a joint article with Spiro [Jacobson/Spiro (1994)], this becomes a »cognitively based Contextual Analysis Framework«, which aims at the typology and classification of forms of computer-supported teaching. The framework knows Spiro's differentiation of contents into »well-structured« and »ill-structured« as criterion #1, adds the learner's level of knowledge (beginner, advanced) as second criterion and looks at their combination in different learning environments. The constellations resulting from this are then called TBLEs (Types of Technology-Based Learning Environments). The arbitrariness of such classifications becomes particularly obvious here. Why the construct of »ill-structured domains« should be one of three central criteria, remains incomprehensible. Why the level of knowledge and not learning conditions, styles of learning, or the learners' attitude and their motivation serve as second criterion, why forms of interaction could not form a third criterion, etc., all this remains unexplained. Seel (1992), who wants to improve the methodical components for decisions in ID systems, straight away resorts to a »Prescriptive Decision Theory«. And it is even more absurd to assign theory rank to a »Button Theory«, a proposal to use buttons for activating several canned messages which interact with the computer-based tutor instead of natural language tutor, a proposal stemming from the Roger Schank group [Schank/Jona (1991); Looi (1994)].

Reigeluth takes a similar approach in the attempt to classify characteristics of simulations [Reigeluth/Schwartz (1989)]. On the basis of extensive research on simulations and the literature on simulations (neither of which are reported in the article, nor is there any bibliographical reference) they propose that simulations consist of a scenario, an underlying model, and an overlay for instruction. They concentrate on the latter aspect in their article. They distinguish between three types of simulations here: procedural simulations, process simulations and causal simulations. In simulation learning, they distinguish three phases: acquire, apply and assessment (Anderson shines through here). In these phases, learning can be supported through characteristics of the simulation, which they call generality, example, practice, feedback, and help (Gagné and Merrill shine through here). As a further characteristic, they type the form of representation of simulations as enactive, iconic, visual or verbal-symbolic with Bruner. These aspects and distinctions, taken eclectically from the literature and combined in a matrix, are then commented on by Reigeluth and Schwartz with recommendations on simulation design, and are designated as a prescriptive theory for the design of computer-supported simulations.

Deficits of Theories of Instruction

We have to look more closely at three areas if we want to know what potential performance instructional design can offer on the one hand, and what fundamental limitations there are for ID on the other hand: restrictions in the presentation of knowledge, preferences in didactic methods, and the picture of learner and learning process implicitly painted by instructional design.

Restrictions in the Knowledge Domain

The knowledge model in instructional design is restricted in several ways: by the kind of learning objectives, by the methodology of determining learning objectives, and by the deductive methodology of designing learning units.

Correspondence Hypothesis

Instructional design aims at training cognitive skills, declarative knowledge and procedural knowledge, with some applications restricted to declarative knowledge and others to procedural knowledge. The concept of the mind as a storage system plays an important part in ID, with different kinds of storage assumed for declarative and procedural knowledge [Tennyson/Rasch (1988)]. The validity of the assumption that defined knowledge is stored directly has been challenged by constructivism [Clancey (1989)], and been subjected to intensive criticism in Carroll's (1990) book »The Nuremberg Funnel«.

Objectivism

In essence, ID-systems know only declarative and procedural knowledge. With regard to a cognition theoretical claim, there is only a programmatic approach [Tennyson/Rasch (1988)]. The term cognitionis being used so widely now, however, for example in the sense of Bloom's cognitive learning objectives, that it can also cover the terminology of instructionalism. But the kind of knowledge instructional design deals with basically consists of just a classification of tasks and actions, and still covers only observable actions, as behaviourism does: »Current cognitive theory is mainly a theory about cognitive skills. Consequently, its instructional implications pertain mainly to skill training« [Ohlsson (1992), 73]. Ohlsson thinks that this condition of instructional design could be excused with reference to the state of cognition psychology, but he qualifies: »This response is correct, but I nevertheless believe that it does not capture the essence of the current situation. In this chapter I argue that our current theory of human cognition – using the term theory in a broad sense – is inherently incapable of producing a revolution in the design of instruction. The reason is, briefly put, that our current theory is a theory of action, rather than a theory of knowledge, in spite of claims to the contrary. Consequently its instructional implications pertain to learning how to act, to skill training. But skill training is, in general, not problematic. Parents, teachers, coaches, and trade masters know how to teach skills« [Ohlsson (1990), 562]. The objectivism of the instructional model violates the cognition-psychological hypothesis that learning always implies a change in the existing cognitive concepts. Wildman (1981) has pointed out early on that one must imagine learning in the form of reciprocal, cognitive processes of assimilation and accommodation, while many models assumed that new knowledge was simply »tacked on« to or »attached « to old knowledge (16).[9]

9. With regard to this point, connectionism is more advanced than the approaches of a physical symbol system hypothesis or symbolic information processing which are reported here. This can be seen in Varela's (1990) attempt to combine the principle of emergence from constructivism with the parallel-processing and self-modifying neural networks of connectionism (58ff).

The claim to include something like metacognitive goals which are needed for problem-solving processes, discovery learning, and creative, constructive processes, is always present in Merrill or Tennyson, but it is only a claim. If we look more closely at what Tennyson understands by contextual knowledge, it becomes clear in what way this term is instrumentalized within the framework of instructional design: Tennyson and Rasch (1988) define contextual knowledge as knowledge which »focuses on the learner's acquisition of the organization and accessibility of a knowledge base for a particular domain« (375). This so-called contextual knowledge is a framework for declarative and procedural knowledge of the domain, rather than what constructivism calls »situated knowledge«. Contextual knowledge in Tennyson's sense is once again objectifiable knowledge, analysable, definable, and storable, and has nothing to do with the social embedding of the learner's spontaneous cognitive constructions.

The instructional model only deals with skills, not with attitudes. The relation between instruction and motivation is an open problem. Psychological factors like evasion, digression, listlessness, a desire for change etc., are not contained in instructional models: »psychological processes that mediate between stimuli and responses are still often ignored« [Winn (1990), 64]. There are approaches attempting to solve this problem even here: Okey and Santiago (1991) discuss how Keller's motivational constructs could be integrated into Gagné's inventory. Nor are preconditions of learning and individual differences between learners taken into consideration in instructional design. The reason for this, as Winn (1993) stresses, lies in the»unmanageable complexity of a prescriptive theory of individual differences« (197). According to Winn, the introduction of learner control in instructional design is motivated mostly by the difficulty of achieving an adaptivity to individual differences in the program. All the same, he comes to the conclusion that »none of the approaches instructional designers have taken to dealing with individual differences has really worked« (198).

Task Analysis

The concepts, rules and procedures for instruction are gained through subject analyses and task analyses, and conceptualized in the form of learning objectives. The importance of the term cognition for the goals of instructional design must be seen in connection with the fact that these goals are defined through task analysis rather than (as in Piaget) an analysis of thinking and learning processes on the basis of a theory of cognition. Varela (1990) complains that Piaget's theory has »not at all found its way into cognitivist orthodoxy« (20). ID must therefore be seen as essentially a »predominantly applied behaviorally-oriented learning paradigm« [Tennyson/Rasch (1988), 369]. Task analysis utilizes the behaviourist assumption that learning results must consist of observable behaviour: »Task analysis has subsequently evolved into a sophisticated technique that identifies extended sequences and hierarchies of behaviors [...] It has even been extended to embrace cognitive theory [...] It still carries with it, however, a reductionist approach to instructional decision-making which, while not antithetical to some aspects of cognitive theory, is sometimes problematic« [Winn (1990), 55]. The process is time-consuming and arduous. This may explain why one has mainly stuck to clearly comprehensible and limited topics up to now, such as simple arithmetic or Newtonian physics. There was probably an initial hope that one would find small building blocks in this way which could then one by one be assembled into more general abilities in the manner of Popper's piecemeal technology. But this expectation has given way to the realization that the abilities which are gained in a specific set of problems remain tied to that particular knowledge domain.

Instructional design represents a deductive approach: the designing process moves from learning objectives via teaching methods to learning processes. In such a deductive approach, unsolvable problems already appear in the process of determining learning objectives and in the operationalization of learning objectives. In some cases, the process of determination is still seen as a purely empirical-analytical process, which however cannot be solved in this way [Flechsig (1971)]. An empirical determination of learning objectives is unthinkable without normative contributions. The operationalizations to be developed out of the determined learning objectives cannot be produced in a purely deductive way [for alternatives, cf. Meyer (1972)]. It would be necessary to reinterpret learning objectives as heuristic methods in a hermeneutic-social process. But this is inconceivable in the framework of instructional design.

The tasks of schools and universities are much too complex to make us draw hope from approaches of this kind. Science has more than once made the mistake of Taylorizing and accumulating until a paradigm shift threw everything out. Cognition psychology had rung in a paradigm shift from behaviourism in a move towards more integral conceptions. The instructionalists are now in danger of following a similar way of fragmentation. I see constructivism as a clear reaction to this situation, as an attempt to take up an integral position towards learning again.

Reducing the Didactic Methods

One methodological problem in instructional design exists with regard to the assignation of learning objectives to methods, with the relation between them seen as deductive-linear. What is intended are basically deterministic systems which directly assign certain methods to certain learning objectives, but »our design procedures do not always allow us to determine, with any degree of efficiency, the optimal course for action« [Winn (1987), 61]. For the positivist, the reason for this imprecision can only lie in the fact that one has not as yet discovered all relevant principles [Winn (1987)], whereas from a methodological point of view one would have to accept the fundamental discrepancy between general criteria and their practical realization. The translation of general principles into practice can assume a probabilistic character at best. One cannot infer learning results from cognitive learning objectives and didactic methods with absolute certainty, but only with a certain probability. Since deduction is not possible, Merrill and Li (1989) make do with probability charts in ID Expert. This modification does not change the model's deterministic character , because even then instructional design is inherently dependent on legitimizing the efficiency and validity of its methodology through probabilistic assumptions about the executed prescriptions [Reigeluth (1983b)].

Winn (1987) emphasizes that in comparison to natural science, prescriptions in instructional design are considerably weaker: »we note the suggestion that our design procedures cannot effect the degree of optimization that is typical in the harder sciences, that our prescriptive theory is incomplete, non-deterministic and lacks predictive validity« (63). And he concludes that the striving for perfection and precision in the instructional design approaches will remain futile: »it is the very nature of prescriptive theories to be non-deterministic […] it will never become foolproof« (65). For Winn, instructional design does not seem sensible on this basis, he argues for a fundamental change of concept: »However, attention to those aspects of cognitive theory that we have examined leads to the conclusion that further changes to thinking and actions of instruction designers are necessary« (1990, 63).

Expository Teaching

Theories of instruction are prescriptive [Lowyck/Elen (1992)] and essentially strive for a predictive validity as high as possible. Instruction thus turns into an expository model of teaching which »heavily depends on the assumption that student's reactions can be anticipated and controlled« (218). Even if the instructionalists think that they have left their initial behaviourist foundation, they still carry with them the behaviourist approach, which sees teaching as induction and the learner as reacting, and the assumption that one has learned the whole if one has identified and learned the parts of the whole [Winn (1990); cf. Bonner (1988)].

I wonder how such a model of science could become dominant with the instructionalists. It seems that the introduction of the computer as means of instruction has changed the medium, but not the desire for rule-governed, deductive construction of learning on the basis of a domain of learning objectives. The pedagogue does not have much freedom in instructional design. The need for planning and safety dominates. Did instructionalism grow out of the need to put a limit to too much choice in decision-making? Is instructionalism not after all approaching the kind of control that behaviourist authoring systems had over the learner?

The basic model is the teacher-centred, expository approach. Even if learner control is a very central topic in instructional design [s. Merrill (1980); Chung/Reigeluth (1992)], reality often looks different: »Often the student is denied control of the interaction« [Lippert (1989), 11]. The expository approach assumes that the optimal structure of learning corresponds to the structure of the subject to be learned. If this assumption is true, then the designer has no choice but to prescribe the structure of the subject area: »The designer who makes decisions on the basis of cognitive theory assumes that the thought processes of the student will be as logical as the instruction itself. As Streibel (1986) puts it, in a different context, in order to learn from a machine, the student has to think like a machine« [Winn (1990), 53].

Instruction as Functionalist Socialization

Very much in this spirit, Jones, Li and Merrill (1990) describe the conception which instructional design has of learning as a kind of Nuremberg Funnel. It is interesting in this respect that they consciously paint the intention of instructional design as indoctrination (as a ban on individual interpretations). They hereby–without any self-critical intention – put the control problem of pedagogics into words, they are concerned with the acceptance of codified knowledge and socially frozen meanings: »The philosophical question of the nature of meaning can be safely ignored. Instruction, in large measure, communicates accepted meaning. The developer of instruction explicitly desires that the learner adopt the meaning intended by the developer, and not reach a separate and personal interpretation of that meaning. Although being able to reach such personal interpretation is an important part of being educated, most instruction, particularly most uses of automated instruction, concerns transferring, as effectively and efficiently as possible, determined interpretations« (12) [my italics, R.S]. Understandably, this conception, which implies both a reification of subjects and a passive learner image, has been severely attacked by the constructivists. One can see in this attitude of instructionalism a correspondence to functionalist conceptions of society and socialization which cultural anthropologists like Lave characterize as follows: »functional theory treats processes of socialization (including learning in school) as passive, and culture as a pool of information transmitted from one generation to the next, accurately, with verisimilitude« (8).

Can this 'behaviourist' approach [Case/Bereiter (1984)], which prescribes (learning) behaviour, be made compatible with cognitive theories [s.a. Andrews/Goodson (1980)]? Lowyck and Elen (1992) distinguish approaches that strive for a deduction of prescriptive learning instructions from descriptive cognition-psychological principles from those that do not think a translation of descriptive cognitive structures into learning instructions possible. They depict instructional models on three scales, according to the degree of the transition from description to prescription, the degree of approach to constructivism, and the degree of compatibility with cognitive theories of learning. They discuss the degree of compatibility of cognitive theories of learning and instructional design and the differences between instructional models resulting from this under the following criteria: Translation (how directly are goals translated into instructions), adaptation (degree of learner control), separation (learning vs. instruction), reconceptualization (active learning through cognitive basis), and revolution (complete incompatibility between cognitive psychology and instructionalism). While Wildman argues for a »cohesive theory of learning«, which must be made to underlie instruction theories [s.a. Wildman/Burton (1981)], Lowyck and Elen come out in favour of a reconceptualization of instruction(220): »Not an integration but a complete reconceptualization of I.D. is needed, which implies (1) selection of cognitive design parameters, (2) construction of a suitable development process and (3) adequate instrumentation of the selected parameters« (218). They admit, however, that it is doubtful whether this position will lead to new ID models or to completely different concepts, such as, for example, the constructivist learning environments.

Some designers see a way out of the prescriptive instructional model in a combination of instructional design with learner models, like those described in the next chapter, which can adapt to the learner's needs through the strategy of flexible response and would thus be able to hand over control to the learner. But Hammond (1989) points out that well-founded learning systems do not have to be based on explicit models of the learner's current state of knowledge and his deviation from the knowledge of the experts. Using a learner model even has specific drawbacks: »The requirement that the instructional dialogue should be driven by an explicit model of the student's state of knowledge places extreme constraints on the freedom that the learner can enjoy« (171). If one were to take the instructionalists' idea seriously, the theory-oriented instruction which automatic design programs strive for would require not only a theory of goals and a theory of the learner, but also a theory of the teacher. But instructional design has basically limited itself to the first aspect.[10]

Another problem beyond the deduction problem is the inherent compulsion of these systems to mastery learning, i.e. to a complete mastery of all concepts and deductions of the learning objectives determined by task analysis. In a study on the perception of user interfaces, Mayes, Draper et al (1988) found out, however, that learners only remember those characteristics of the user interface which enable them to recognize and execute certain tasks, while other factors are quickly banished from memory: »It seems that the necessary information is picked up, used, and discarded; it is not learned in the sense that commands are learned. More exactly, users retain only enough information for recognition, not the much greater amount required for recall« [Mayes (1992b), 9/10]. If, accordingly, it is sufficient to merely retain essential information in order to be able to solve future problems, then the principle of mastery learning is wrongly situated.

10. An alternative of a completely different kind is proposed by Carroll (1990), who hails from Human Interface Design; the so-called minimalist instruction as strategy for training designs, which is to exhibit three components: "(1) allowing learners to start immediately on meaningfully realistic tasks, (2) reducing the amount of reading and other passive activity in training, and (3) helping to make errors and error recovery less traumatic and more pedagogically productive." (7)

The sequentiality of framework-based instructional systems probably presents a similar problem for the cognitivist notion of concept learning. There is evidence that several processes are running parallel in concept learning. One indication of this could be Ranzijn's (1991) findings, who demonstrates that simultaneous presentation produces better learning results in learning coordinate natural concepts. His experiment even shows better results for the simultaneous method for sequential natural concepts. Simultaneity enables comparison: »By comparing and contrasting expository examples of coordinate concepts, the student develops more elaborate and complete conceptual knowledge« (417). Such an insight surely speaks rather for network systems in the sense of connectionism, or hypertext systems.

Descriptive concepts of self-regulated learning come to entirely different characterizations of the learning process. Completely different terms of description play a role here than in the learning-goals-oriented taxonomies of learning conditions and learning results, e.g. challenge, confrontation, surprise, mystery. Vermunt and van Rijswijk (1988), who describe processes and regulations in self-regulated learning, notice to their surprise, however, that students apparently do not become »wiser« or more self-regulated with the years, but more externally regulated and reproduction-oriented. This may of course be a result of the dominance of expository instruction and reproductive learning situations in their learning environment.

Confounding the Concept of Learning

Substitution of the Institutional Concept of Learning for the Biological Concept

Even in a methodologically thoughtful proponent like Landa (1983a) we can see in the arbitrary distinction between cognition and learning and between understanding and learning just how restrictive the concept of learning is in instructionalism: »Cognitive processes (and operations as their components) and learning are, however, not synonymous. When a person performs some operation (say, on a sentence) in order just to understand it, his or her operations are cognitive, but not learning. But when the person performs the same operations on a text in order to learn it (i.e., when some cognitive operations function as means of learning), then they become learning operations« (64) [my italics, R.S.]. For Landa, identical operations sometimes represent learning and sometimes »merely« understanding. The intention determines what is learning and what understanding. Accordingly, it is possible to have understanding without learning. What an odd notion of understanding! This opposition of learning and understanding is based on a concept of cognition as tool: you apply a ready-made operation to something with the intention of either understanding or learning it. Against that concept , I set this thesis: objectively, learning and understanding take place with every action of the active individual, regardless of the learning individual's consciousness; incidental learning and understanding are inevitable, understanding cannot come about without modification of individual cognitions by assimilation and accommodation, although the same process can be either intentional learning or simple action from the learning individual's point of view! If we contrast Maturana's conception with Landa's, it becomes clear in what way instructionalism exhibits a reification of the concept of learning, a reduction of learning to intentional, planned processes induced by the teacher, that is, a substitution of the institutional concept of learning for the biological concept.

Objectification of Cognition

There is a similar reification with regard to the notion of »concept« (i.e. cognitive concept) among the instructionalists. Landa (1983) describes the following example: »But a person who may have a mental image of an isosceles triangle and may be able to draw it on paper may not be aware of its characteristic features and may not be able to answer the question, 'What is an isosceles triangle?' by describing its characteristic features. This means that he or she has an image of it but does not have its concept« (167). This example is a bit more complicated to analyse. The child does not have symbolic representation of the cognitive concept at its disposal, but it is well able to execute cognitive operations in a concrete form. There are many examples for Landa's observation in Piaget and Bruner. But what conclusions do instructionalists draw from this? Landa claims that the individual in question does not have a concept but only an »image«! Instructional design apparently assumes that only the formal version of the concept is a concept at all, and that therefore the formal version must be learned. This restriction of the notion of concept confounds the learning process with the learning objective: The instructionalist learning objective is reified into an object which must be learned, while the existing »image« is neglected as irrelevant. Duffy and Bednar (1991) stress in contrast to the objectivist position that there can be »no prespecification of content to learn« in constructivist learning (14), and that the instructionalists' expectation »that each learner will take the same thing away from the learning experience« is not correct. Authentic learning processes cannot bear the notion that a highly specified meaning is to be taken over, or that an already existing concept is merely to be applied to a given situation like a tool.

Winn (1987) emphasizes that decisions are made both in instructional design and by the teacher in an actual classroom. But instructional design and the actual classroom differ widely in that the teacher will have an instructional plan, but may at any time make new decisions: »The great difference between them lies in when those decisions are made […] In teaching, while instructional decisions are often made during lesson-planning, it is highly likely that decisions will also be made on the spot by the teacher« (59). There are many studies on the teaching decisions of teachers which analyse the commonplace knowledge and hidden processes of decision-making in order to process them for imitation in ID systems. Wildman (1981), who still thinks that it might be possible to conceptualize such functions of teachers as moderators in instructional design, stresses that »designers must be familiar with the reciprocal processes of assimilation and accommodation and arrange to provide support when they occur« (16). But teacher behaviour goes far beyond this: The teacher does not only analyse the pupils' cognitive level, but also the psychological factors in the situation, the pupils' motivation. Accordingly, he chooses strategies that ID systems do not have at their disposal, analogies from completely different domains, pictorial translations, narrative illustrations and other media. The teacher as a rule falls back on the pupils' experience rather than their knowledge. The variance which a teacher has at his disposal is always greater than that of a database or a knowledge base written in the form of rules.

From Instruction to Learning

The switch from instruction to learning is on the agenda. Wildman (1981) puts it into words relatively early: »I will suggest a second way to see the nature of the impact of cognitive theory on design work is to consider what must be done to incorporate the notion of learning as change in cognitive structure« (17). Wildman still harbours a hope of realizing this notion within instructional design. But this is mostly due to the fact that Wildman like Merrill assumes a reified notion of concept which sees cognition as categories of a discipline which are to be recorded through task analysis and mediated accordingly.

Learner Control vs. Program Control

I am dealing with the problem of learner control here in the chapter on instructional design, because, owing to the origin of instructionalism in behaviourism and the clear orientation of instruction of designer to learner, the question of the importance of learner control comes up most violently in this context, as Merrill's (1980) relatively early discussion of this subject shows, whereas the other types of software discussed in this book realize a much higher degree of learner control in their design. In order not to have to come back to this topic over and over again, I will deal with it in detail at this point.

By learner control in computer-supported learning, one understands the learner's control over the choice and sequencing of topics or exercises. Merrill (1980) distinguishes an additional learner control relating to choice of strategy (e.g. of the level of difficulty, of examples). Often, the learner's control with regard to the time spent on the exercises is also erroneously subsumed under this term, a phenomenon usually treated under the heading of »self-paced study« [Merrill (1980)]. Chung and Reigeluth (1992) break down learner control into control over content, sequence, speed of learning, display or strategy, the internal process, and the advisory strategy. There is a large number of studies on learner control. But most studies do not describe the environment which they test. This is, however, absolutely necessary, since learner control can assume completely different meanings according to the respective environment (courseware, instructional design, intelligent tutoring systems, hypertext, simulation).

Learner Control in Authoring Systems

Merrill has attempted to incorporate learner control into TICCIT. Learner control in TICCIT was already recognizable externally through the 15 learner control keys on the keyboard: ATT'N, EXIT, REPEAT, GO, SKIP, BACK, OBJ'TIVE, MAP, ADVICE, HELP, HARD, EASY, RULE, EXAMPLE, PRACTICE. With the help of these keys, the pupils could switch to the next exercise, go back to the previous exercise, skip an exercise, choose the level of difficulty, choose the form of display (rule, example, practice), and call for help and advice. In other words: Within the framework-based architecture of TICCIT, the pupils could at least navigate on their own, check their position within a lesson or unit by way of maps, adapt the level of difficulty to their own learning conditions in three stages, and get help. Merrill specifically points out that the extent to which these control options are used by the learners and work effectively depends on the degree of internal control over cognitive strategy which is given to the learner (89), so that an aimless use of these methods could just as well contribute to a falling off in performance with some pupils. In principle, there are four possible conscious strategies of control: selection of contents, selection of displays, conscious cognition and metacognition. By conscious cognition, Merrill understands such strategies of thinking that the pupil chooses in a relatively conscious way in order to be better able to learn a lesson, e.g. repeating, calling for a pictorial illustration, calling for an example, producing an analogy, etc. By metacognition, Merrill understands the cognitive ability to learn itself, the »How« of learning. Each pupil is internally working with models of learning which do not necessarily correspond to those of the instruction.

It should have become clear from this example that in instructional design learner control means a limited selection of display variants within the framework-based structure of an instruction design. TICCIT cannot exert an influence on the pupils' own internal cognitive processes. It should also have become clear from this example that adaptivity in the sense of individual adaptation is only possible indirectly in instructional design via learner control, and only to a limited extent. Adaptivity is the real reason for the introduction of learner control in instructional design, because the multitude of individual differences in learning preconditions and attitudes cannot be incorporated into the predictive principles in instructional design [Winn (1993), 196].

Why Learner Control?

There are pedagogic grounds for an intensified steering of the learner (= program control), and there are also pedagogic grounds for a stronger control of the learner over the program (= learner control). I will set some views against each other here without commenting on them, and give a review of evaluation studies on this topic in the following section.

Depover and Quintin (1992) argue for more learner control. They cite two reasons for a strengthening of learner control:

- First, they suppose a positive effect of learner control on cognitive learning objectives: »the notion that control by the student (in part or completely) would lead to induced benefits such as the development of certain metacognitive skills is now commonly accepted« (236). They assume, however, that metacognitive skills are not spontaneously formed through learner control alone, but that additional structuring elements must be provided.
- Second, they hit on the apparent weakness of Artificial Intelligence in developing an efficient learner model for intelligent tutoring systems with adaptive strategies, and see an opportunity to achieve greater adaptivity by a more even distribution of learner and program control: »This inability to discern learner characteristics, in addition to the difficulty in arriving to a format of the field being teached that is sufficiently flexible to permit a real adaptive tutorial (Clancey, 1987) have lead certain authors to propose intelligent instructional models where the control is distributed between the system and the learner« (236).

There are no open arguments against learner control, there are only arguments for and against the degree of learner control. Depover and Quintin make the degree of learner control dependent on variables like age, previous knowledge, learning progress, complexity of material and familiarity with the subject (237). The other side sticks to the argument for a lesser degree of learner control immanent in their respective systems. McCalla (1992b) for example justifies the necessity of the demand for learner models with the aim of individualization. Therefore, learner control is only possible for him with a learner model: »Without detailed knowledge of what students actually do, it is impossible to allow the student any control« (112). He clearly demonstrates the desire to direct the student, whom he only wants to entrust with control over the program if the program knows exactly where the learner is. But this specific program-controlled form of learner control cannot reasonably be viewed as learner control any more. It is rather an adaptive instruction strategy which constitutes a more sophisticated form of program control than program control of the behaviourist stamp has ever been able to offer.

Pessimism about the consequences of learner control also reveals the motives for a restriction of learner control: »There is an inherent danger in the provision of more flexibility, more power and more features in tutors and environments for novices. This is that the load on the student for learning about the system itself is out of proportion compared to the learning load associated with the target programming skills. As windows proliferate and mouse sensitive icons litter the screen the student can become overwhelmed« [du Boulay (1992), 196]. What a misjudgement! The very iconic interfaces that have allowed even four-year-olds to play actively with interactive animated electronic books are cited as a reason why pupils should be controlled more firmly.

Are Depover's and Quintin's hypotheses justified? Or does learner control represent an excessive trust in learners (McCalla), or does it mean overtaxing the learner (du Boulay)? These are the questions that come to mind here. It is not easy to find answers to them, not even if we make a thorough study of the studies and secondary analyses of learner control. Too many intermittent variables play a role here: The functionality of learner control depends on the demands which the learning environment makes on the learner, the expectations students have of the institution, the learner's stage of experience, and the form of the intended task or learning situation.

Studies on Learner Control

The simple expedient of substituting learner control for program control, shifting the focus of interaction from the instruction system to the learner, does not seem to bring about the expected success. Borsook and Higgenbotham-Wheat (1991) think that their overview over studies on this problem has shown: more learner control »results in disappointing performance« (13). Perhaps learner control is not positive for every learner and under any conditions?

In some studies, undesired interactions between program and interaction occur, in others, testing conditions do not correspond to the experimental effects:

Lee and Wong (1989) find, for example, that students deal with more examples under learner control, that is they are more active, but that they are less successful in post-testing with regard to precision than students under the conditions of program control. They put this difference down to the fact that learner control allowed undisciplined sequencing, i.e. it allowed something that was inappropriate to the testing condition »precision«.

Milheim (1990) studied the effects of learner control and independent pacing with 99 students in an interactive video exercise on photography. Learner control in this case meant control over the sequence of learning and pacing; with program control there was also a distinction between prescribed pace and self-pacing. Milheim chose a variance design of 2x2x2. Learner control with regard to pacing proved to have a significant effect on learning objectives, the other conditions did not result in any differences.

Arnone and Grabowski (1991) evaluated learner control with an interactive laser disc program on art education and its effect on the curiosity behaviour of children. The program simulated a visit at the Everson Museum in Syracuse, New York. 103 first and second graders were distributed into three sets of learning conditions (program control, learner control, learner control with advice) and one control group. Post-testing chekked learning results and curiosity. The children in the learner control with advice group showed the best results in the performance test, and they also showed higher values in the scales for curiosity.

Hasselerharm and Leemkuil (1990) compare three different conditions with each other: LC (learner control with optional advice), PC (non-adaptive program control) and APC (adaptive program control) in relation to previous knowledge and the cognitive style of field independency vs. field dependency. The APC condition was most successful over all, the LC condition proved to be unsuccessful with weaker learners. Previous knowledge and the type of exercise had great influence on the success of learning in LC. Nevertheless, the LC students assessed their system much more positively than the students in the two control groups. The authors see a possible explanation in the fact that the students did not have sufficient experience in varying their own learning. They recommend more freedom for learners in CAI, provided that there is more training in self-regulation. LC systems are not recommended, however, for weaker students (78).

Secondary Analyses

Steinberg's (1977) secondary analysis of learner control studies in computer-supported instruction until 1977, and Steinberg's (1989) complementary secondary analysis about studies between 1977 and 1988, come to negative conclusions with regard to the effectiveness of learner control. In the secondary analysis of 1977, she reached this conclusion: »for the most part, students learned less when given control over instructional sequence. High performers in the subject area were most likely to be skillful managers of instruction. Students were not very proficient at selecting exercises at appropriate difficulty levels […] The motivational benefits of learner control were not accompanied by better performance. Learner control sometimes resulted in greater task engagement and better attitudes, but not necessarily in greater achievement«. One must of course consider the historical starting point of this study: What kind of programs could have existed before 1977? How were the motivational, cognitive, and affective variables controlled at the time? In which instructional designs were the studies conducted? etc. Steinberg's more recent secondary analysis of studies with regard to interactive laser disc systems, a decade later, tries to avoid theses imprecisions. But her result remains the same: »Students do not perform as well under learner control as under adaptive computer control« (118). While the results of earlier studies might be explained by the fact that they did not consider the psychological factors of the learning process, this was not the case with the later studies. But one may put forward a few critical objections with these as well:

- The didactic quality of the learning environments was not comparable. These are, for example, test subjects' comments on the help offered in one experiment: »Some said either that the computer help was too much of a crutch while others commented that it took away the challenge!« (120)
- In some cases, the division into groups with and without learner control – considering the triviality of the tasks – is absurd, and one thus cannot speak of a genuine »learner control« test condition.
- In other cases, additional tutorial feedback was given to the control group but not to the test group, so that a stronger variable may have cancelled the effect of the weaker one.

Moreover, the choice of represented studies and Steinberg's qualitative procedure may be highly selective. Gay, Trumbull et al (1988) come to a clear positive conclusion in favour of learner control in their literature overview on computer-supported video instruction. Ambrose (1991), who reports studies about learner control in hypermedia systems, also tends toward a rather positive assessment: Learner control seems to have advantages, it offers a possible involvement of the user.

Meta-Analyses

McNeil's and Nelson's (1991) quantitative meta-analysis of studies about interactive video (IV) since 1978, on the other hand, again reaches conclusions similar to Steinberg's. This meta-analysis also included some studies (26,2%) among the 63 studies taken up for analysis which examined the learner control variables. In studies which did not offer control of sequence to the test subjects, the learning result seemed to be better than in studies with learner control. The authors construe an argument for guided learning from this: »This may be further evidence that IV is best accomplished when it is guided and structured as opposed to being entirely under the control of the learner« (5).

These are only a few examples of many studies about the problem of learner control. Many come to negative, but just as many to positive conclusions. The weaknesses of these studies lie in the following deficits:

- The experiments use completely different learning environments, which can often only be guessed at by way of the language used in the study: tasks, exercises, tutorials, IT systems, KIOSK systems, hypertext systems. The teaching programs used in the experiments are not described in most cases. In this way, it becomes impossible to understand what elements were counted as program control or learner control respectively. It is not possible, moreover, to assess the effect of the program's quality on the achievement variables in post-testing. If there are no significant differences in achievement, this may be due to the dominant effect of a good program (the novelty effect) or to the stronger effect of an intermittent variable. The meta-analyses do not even contain data for most of these variables [McNeil/Nelson (1991), 5].
- Psychological variables are not controlled as a rule, although the few studies that do control learning styles after Entwistle or Kolb, or variables like field dependency and efficiency, immediately come to subtly diversified results with regard to sub-samples. The omission of these variables in the studies and meta-analyses may be responsible for the high percentage of unexplained variance which is reported in some studies [McNeil/Nelson (1991), 5].
- For some reason, most researchers choose beginners for such studies, as if the question of learner control had to be tested in virgin soil. Yet it would sometimes be sensible to rule out beginners' problems of getting used to the programs by choosing experienced users or even professionals for such experiments.

- It was not examined whether there are significant differences in results when the test subjects know under which condition of learner/program control they are working. Studies on navigation in hypermedia systems, which are sometimes quite close to the problem of learner control, have given decisive indications of the role of »awareness« [e.g. Trumbull/Gay et al (1992)].

What role does learner control play if students are aware of it? Kinzie, Sullivan et al (1992) have investigated this question. They studied the effects of learner and program control on 81 male and 83 female 9th grade pupils. The pupils were also asked to choose their preferred method in a follow-up session. The experiment was concluded with a post test. Program control was more successful with male pupils, learner control led to a non-significant advantage with the female pupils. But one result was indisputable: The percentage of pupils who again chose learner control for their follow-up session was definitely higher.

Self-Paced Study

The next three studies dealing with »pacing« or »self-paced study« have little to add to the learner control debate. Merrill (1980) had expressly excluded these topics from the field of learner control. I cite them nonetheless, because I want to point to same lateral aspects of the problem which are important for an overall assessment:

Smith (1990) experimented with forced breaks in an interactive laser disc system. The results show that forced breaks in strategic points can advance the learning achievement with some students without impeding that of the others.

Hicken, Sullivan et al (1992) varied the topic learner control vs. program control by allowing the students under program control conditions to skip optional exercises, and allowing the students under learner control conditions to choose optional exercises in addition to a compulsory core of exercises. The first condition (passive deselection) proved to be more successful than the second (active selection). It seems to me, however, that this kind of condition does no longer allow drawing conclusions about the problem learner control vs. program control.

Hoelscher (1990) studies law students with an interactive video program. All received instructions and tasks. One group received an additional list of case-solving strategies. The students were assigned to one of the two conditions in pairs. After 90 minutes, they had to formulate three criteria for a legal charge. This experiment was accompanied with methods of participatory observation, the students were interviewed and had to fill in a questionnaire. The results showed that the pairs who were given the additional list with solving strategies turned out better charges in the end. This study has only little to do with learner control, since the difference clearly lay in missing metacognitive information or abilities, which should have been an integral part of the program. The students must have felt this, because 70% of the non-guided pairs asked for additional instructions, while only 40% of the guided pairs did the same. Designating the test groups as »guided« and »non-guided« is thus misleading. But the hint which this study gives us with regard to the relevancy of the learning material's didactic structure is interesting all the same.

Discussion

Chung and Reigeluth (1992) formulate instructional prescriptions for six methods of learner control. For hypermedia systems in particular, they schedule the following guidelines for learner control: 1. Guidance for weak learners (determination of a path, Guided Tour), 2. Graphical browsers, 3. Audit Trails, 4. standards for display design, 5. Learner-defined conceptual links. With Chung and Reigeluth learner control reaches a long way into program design: in effect, they deal with nothing more than general guidelines for multimedia, such as unlimited undo-options, help offers, the use of common metaphors. Their intention is transparent: Learner control for them also includes protecting the system against weak, inexperienced, lost, or in any other way non-optimal learners. Learner control here again turns into control of learning, i.e. the system's control over the learner is substituted for the learner's control over the system. Fittingly, their motto reads »Effective and efficient guidance« (18).

Jonassen (1992b), too, claims: »My bias is that hypertext needs to be structured in such a way as to facilitate the acquisition, integration, and synthesis of knowledge« (125). What does Jonassen understand by structuring a hypertext? Is the result of such structuring still a hypertext? Does Jonassen not contradict himself when he claims: »A central hypothesis of this paper is that hypertext is a technology that can effectively facilitate learning, because its access and information structures closely resemble the learning process« (127, my italics, R.S.). If hypertext already corresponds to the structure of learning processes in its original structure, why do I have to structure hypertext? [I will go into this correspondence hypothesis in more detail in the chapter on hypertext]. Does Jonassen not contradict himself when he claims, shortly after, that this correspondence does not exist after all, but has to be produced? »Hypertexts that are designed to facilitate learning should reflect models of learning«. Which models of learning is Jonassen referring to? He does not provide an answer for us. If the first hypothesis is true, hypertext should already be compatible to the learning process. If the second hypothesis is true, hypertext would have to be made compatible first.

The principles which Jonassen would like to see realized in transformed hypertexts are terms from his model of instructional design (borrowed from Anderson): *Accretion*, *Restructuring*, *Tuning* and *Sequence*. Behind these principles there are concepts of learning that are partially opposed to hypertext: the restructuring of cognitive concepts occurs by way of an interpretative exploration of the complexity of hypertext, not by pushing a metaphor button, the refinement of schemata occurs by way of learning experience, not through exercises aimed at this specific result. But Jonassen's comments on restructuring deserve some attention in my opinion: The restructuring processes of knowledge are not invariant. The assimilation of new information and concepts occurs at the same time as the accommodation of the existing concepts to new situations and information. Strangely enough, the examples Jonassen refers to are inappropriate for supporting his argument. The experiment to let students generate semantic maps with *SemNet* is a sensible way of supporting restructuring processes through adequate activities. But is has nothing to do with *Accretion*, *Tuning* and *Sequence*. There is a gap in Jonassen's argument between the »scientific« presentation and the »human« enthusiasm for stimulating examples.

Hammond and Allinson (1989) [Hammond (1991); Hammond (1992)] reiterate the hypothesis of getting lost in hypertext like a magic spell. Hammond's fixation on this problem seems to me to have a clear rhetoric function: it serves to legitimize the demand for more control over the learner. In Hammond, the instructional approach makes a comeback: »it [i.e. hypertext] should be supplemented by more directed access and guidance mechanisms« [Hammond/ Allinson (1989), 294; the same sentence can be found in Hammond (1991), 111]. Hammond wants to go back from free hypertexts to planned user interfaces: »The system needs to be tailored both for the generic requirements of learning by the target population of the target domain and specifically for the particular learning task« [Hammond (1992), 150]. In his justification of making hypertext more didactic, Hammond presupposes the existence of learning objectives and learning tasks, i.e. of didactic means which are alien to hypertext systems, that is, he justifies a goal (establishing didacticism) using the goal itself (didacticism) as argument. Hypertext turns into a »learning support environment« with Hammond. It seems to be difficult for pedagogues to credit »being lost« in a flood of information as a pedagogically fruitful experience.

Access to the Domain

Laurillard (1987) chooses a completely different starting point for discussing learner control. Considering experiences with traditional computer-supported tutorials, she wonders whether this form of learning program, which she calls »didactic model«, instruction model, could be freed from its rigidity by way of learner control and become what she calls a »communication model«. Laurillard distinguishes control over sequence (table of contents, map, the possibility of going back to index or contents at any time, jumping backward and forward, retracing previous steps) from control over strategy (looking at examples, doing exercises, taking in information, consulting a glossary, asking for explanations, completing a test) and control over manipulation of contents. For her, the last point is the most important in the learner control discussion. Traditional tutorials are marked by the following features according to Laurillard: They do not allow direct access to the knowledge domain, their knowledge is put down explicitly in the program code, their feedback is extrinsic. In Laurillard's opinion, intelligent tutorials may assume features like direct access to the knowledge domain or supporting learner-defined goals, but they would still remain didactic models of learning. Simulations on the other hand cannot incorporate learner-specific goals, but they allow something else which is decisive, namely direct access to the objects of the knowledge domain. For Laurillard, one can only achieve learner control over the knowledge domain »by allowing the student to act as program author« (15).

Gentner (1992) chooses still another point of departure for the learner control discussion. He reports on programs, learning games and learning programs which do not have either an expert or a tutorial component, but are nevertheless – or perhaps because of this – employed with learners very successfully. He refers to Apple's Human Interface Guidelines, which put the »locus of control« into the user's hands, and are responsible for the users' motivation in his opinion, to deal with programs like Interactive Physics, SimCity, or »Where in the World is Carmen San Diego?«. His conclusion: »student control is a major motivating factor in the learning process« (228).

As the examples just discussed have shown, the decisive element in the learner control discussion seems to be to which teaching strategy the analysed system adheres. Is it based on the instruction model? Does it follow the hypertext philosophy of free navigation? But just as with other evaluation studies, it becomes clear here as well that learner control itself cannot really be evaluated. The differentiation of variables would have to be spread much more widely in the studies than just a distinction of types of learning software. Cronin and Cronin (1992) point out, for example, that studies on learner control suffer from a lack of theoretical foundation, that students are not the best evaluators of their own learning needs, and that the results of studies on learner control would have to be differentiated by learning styles.

Burwell (1991) has executed a differentiation by learning styles in order to »prove« that program control achieves significantly better learning results with students who are field-independent in comparison to field-dependent students, with whom learner control results in higher scores.

One of these differentiations includes the question whether learner control should be combined with advice (or explanations). Schloss, Wisniewski et al (1988) explore in an experiment the question whether advice on top of learner control is efficient in computer-supported learning. They employ explanatory feedback on the students' cumulative performance as »advisement strategy«. The test group achieved clearly higher results and had a more positive attitude when learner control was combined with sufficient advice.

Another differentiation of the overall question is an examination of the assumption that learner control is probably only an action-regulating instrument if it is perceived as such by the learning subjects. Bekker and Dwyer (1994) examine in an experiment whether learner control is recognized as such by the students. This study offers an explanation for those studies in which increased learner control did not show any effect on the learning process, motivation, or attitude.

Almost completely overlooked is the possibly most effective part of learner control, i.e. that of self-evaluation and self-regulation [Simons (1992)], the ability to guide and control one's individual learning independently, an intrinsic feedback structure. Simons demonstrates with his concept of »process-oriented teaching« that this self-regulating ability has an influence on the choice of learning strategies and can lead to an improvement of learning and learning ability.

Criticism of Instructional Design from the Constructivist Point of View

Newell's and Simon's Physical Symbol System Hypothesis

Ohlsson seems intent on attracting attention through especially original ways of looking at a problem and generally putting his foot in . In his article of 1990, he aggressively defends the objectivism attacked by the constructivists, which his comrades-in-arms coyly conceal, or, like Merrill (1991), even deny. For Ohlsson, cognition is a computer: »Human cognition [...] is a species of symbolic computation« (563). He calls upon Newell's and Simon's (1976) »Physical Symbol System Hypothesis« for supporting his thesis that symbols and references are physically stored in the mind: »The world is represented in the mind by symbols, physical structures with reference« (565). For Newell and Simon, the symbol system hypothesis implies that human beings are a special case of physical symbol systems, they are interested in the hypothesis as a sensible working hypothesis for e.g. imitating the processes of language comprehension [cf. Simon/Newell (1964)], with the term 'physical' covering two meanings: The systems can be described through physical laws and can be manipulated in technical systems, and the symbols are not only human symbols. Newell and Simon emphasize: the hypothesis is an empirical generalization, not a theorem. With Ohlsson, the computer analogy loses its hypothetical character, he can only imagine cognition in an objectified form, as if to say, if you can think it, it must exist, i.e. it must be physically present in some place: »Symbol structures have spatio-temporal existence, and hence must reside somewhere«. Cognitive processes are stored programs which execute operations by way of internal representation: »Cognitive processes are caused by the execution of stored programs that operate on an internal, symbolic representation of the world« (563).

Computer Analogy for Cognition

Although Ohlsson restricts the computer analogy a little by remarking, »Information processing models do not capture the entire complexity of the human mind, nor are they intended to. Each model is an idealization and an approximation« (568), he strips mental models of their hypothetical character and imagines them concretely: »Cognitive processes are generated by running cognitive procedures, mental programs, over the stored symbol structures«. The concept of what kind of mental programs these might be is stamped by the computer analogy as well. As operations he regards for example copying a symbol from one storage device to another, comparing two symbols for similarity, deleting a symbol, or writing a symbol into a specific place in the storage device, i.e. typical assembler procedures which have nothing to do with human cognition: cognition does not copy symbols, nor does it write them into specific storage places, compare strings, or delete symbols! According to Ohlsson, more complex operations come about by »stringing together« these primitive operations (566). The cognitive apparatus coping with these processes is also a computer for Ohlsson, which is made up of (1) a language of thought, (2) several storage devices in the mind, (3) a set of procedures, and (4) an interpreter. Ohlsson's »information processing model of the observed performance« (567) goes back to SOAR [Laird/Rosenbloom/Newell (1986)], the architecture for production systems [Neches/Langley et al (1987)]. I go into this in so much detail because the reification of cognition becomes very obvious indeed in Ohlsson's extreme version of cognitive science. We will have to recall this when we repeatedly meet with the correspondence hypothesis and the accusation of objectivism brought against the cognitivists in the following constructivist criticisms.[11]

Hard Noses and Soft Brains: Connectionists and Constructivists

Ohlsson designates cognitive science the »standard theory« of cognition and brands all competing models as »left-wing«- or »right-wing« extremists, a tactics only too well-known from politicians' dealings with political opposition or the church's dealings with infidels. The chapter in which Ohlsson 'takes on' the left and right wings of cognitive theory bears the heading »Hard Noses, Soft Brains«: the hard noses are the connectionists [Rumelhart/McClelland (1986)] and the mental model theory [Anderson (1988)], which according to Ohlsson strive for harder data, a strategy he puts down as 'conservatism', while the constructivists are the soft brains who doubt the physical symbol hypothesis. Constructivism is only dealt with in the last three paragraphs, and even then only in the completely distorted form of disparagement: »TThe left-wing response to the current state of cognitive research is also prepared to give up the idea that knowledge resides in symbols in the head. But instead of nailing knowledge to material structures like brains and environments, researchers leaning towards the left path are prepared to disembody knowledge altogether. Knowledge, they claim, is hovering like so much ectoplasm in the space between the knower and the known […] cognition does not belong to any one person but is socially shared« (596). There is absolutely nothing right in this characterization of constructivism: situated cognition is not 'interpreted contextual knowledge' in Ohlsson's representation, but 'incorporeal' knowledge; to him, the communicative exchange of meaning is knowledge which nobody 'owns'.

11. For criticism of 'token physicalism' and psychological reductionism from a cognition-theoretical perspective, cf. Fodor (1992), from a physics and biology perspective, cf. Penrose (1994). Baumgartner's and Payr's (1995) interviews with »Twenty Eminent Cognitive Scientists« present an interesting collection of contributions to the discussion between symbol-processing cognitive science, connectionism and constructivists. On the dominance of the symbol-processing approach in artificial intelligence research in Germany, cf. Ahrweiler's (1995) criticism. On criticism of the hypothesis of physical symbol-processing from a constructivist perspective, s. Varela (1990), 37ff. Bednar, Cunningham et al (1992) refer to Lakoff's (1987) accusation of objectivism: some cognitive approaches in pedagogics, e.g. instructionalism and symbol-processing, which are based on machine-learning concepts (Newell, Simon, Anderson) treat concepts as objective givens which are independent of the thinking subject. What he means is a quasi-natural scientific concept of cognition as atomistic cognitive concepts which are independent of the subject, but whose representations are effectively stored in human memory.

Brain Research

Only a little insight into modern brain and mind research [Pasemann (1996)] and cognitive neurobiology [Roth (1997)] would have saved the supporters of the computer metaphor from such grotesque misjudgements. Roth (1997) opposes both the analogy in the model of symbolic information processing („of limited use") and „treating cognition as equivalent to stimulation processing in nervous systems", as connectionism does (28/29). Roth supposes that »brain scientists living a hundred years from now will smile at us because of the computer analogy« (90). The very perception directed towards our environment is already constructive and does not copy or imitate (125): „As regards epistemological constructivism, I claim that it follows inevitably from the constructive nature of our brain. A brain – that is my thesis – on principle cannot mirror the world; it must be constructive" (23). The brain's achievement especially must be understood as an »dynamic interaction between a structured environment and the self-organizational process of an autopoietic system« [Pasemann (1996), 81ff], as »non-linear, dissipative systems« (54), in which there are neither physical, material correlates nor permanent storage for representations: »Inner representations of biological brains exist as part-processes of a global cognitive process, and, as such, are not persistent. They only exist as reproducible semantic configurations of module dynamics in small time windows. In this form, they cannot be stored and are only indirectly and ambiguously defined by the brain's linking structures. They do not represent mirror images of an 'objective' external world« (86).

Models of lesson-planning as a rule are based on the notion that one must impart basic building blocks of knowledge, which by and by can be put together to make up a more complex structure. The notion of »basic knowledge« has shaped many concepts of introductory courses and seminars at universities. Constructivism stands this image of accumulated knowledge, which is also present in instructional design, on its head: »Cognitive theory today offers strong reasons to consider such bottom-up instruction suspect. First we know, that human memory for isolated facts is very limited. Knowledge is retained only when embedded in some organizing structure […] Second, we now recognize that skills and knowledge are not independent of the contexts–mental, physical, and social–in which they are used« [Resnick (1989), 3]. In constructivism, the basis is represented by the active occupation of the learner's organizing knowledge structure with practical concepts in their entirety, not by isolated building blocks and didactic abstractions. Laurillard (1987) has put forward the hypothesis that instructional design imparts »preceptual knowledge«, »to distinguish it from the perceptual knowledge we acquire through perception, and from the conceptual knowledge we acquire through social interaction and experience […] Preceptual knowledge is knowledge of precepts, of givens, of what is 'definitely known' in a subject. The dictionary refers to 'preceptive' as 'mandatory, didactic, instructive'« (3). In her view, constructivism does not impart knowledge, but rather offers opportunities for generating perceptual and conceptual knowledge. These two concepts are worlds apart. That the switch from instructionalism to constructivism is also an epistemological paradigm shift is emphasized by Pea (1992): »There are foundational issues beyond the common responses of our field which might provide the radical reconstruction of the epistemological eyeglasses with which we view the significant categories of meaning, learning, and knowledge involved in education« (314).

It is a fundamental paradigm shift that we meet in the dispute of instructionalists with constructivists. Even if one does not want to subscribe to constructivism programmatically, one can see that the paradigm of instruction which was dominant for decades is being slowly superseded by the paradigm of open learning situations, that learning-goal-oriented lesson-planning is being replaced by the arrangement of learning environments. Greeno (1991) utters such an assessment:

> »Some recent discussions have contrasted two different roles for computers in education. I will call these two roles didactic and exploratory. In the didactic view, computers are a tool for presenting instruction in a systematic, individualized way. The instruction is organized to provide for efficient learning with a minimum of student errors. The programs that run these systems include models of student knowledge that are used to diagnose the student's current state. Exercises are chosen or hints are given to make further incremental progress as likely as possible. […] In the exploratory view, learning is treated much less systematically. The computer system presents some phenomena that students can investigate through interactions with the program. The activities allow the student to understand transformations and constraints in the domain. […] These views of computers in education reflect two general views of cognition and learning. The didactic view reflects a theory that considers cognition as a system of information structures and procedures, and learning as acquisition of cognitive structures and procedures. The exploratory view fits better with a theory that considers cognition as activity that is fundamentally situated in social and physical contexts, and learning as strengthening of capabilities for situated activities« (3).

Criticism of Objectivism

Clancey (1992) discusses the accusation of objectivism and the identity hypothesis, and demonstrates that artificial intelligence, despite claims to the contrary, always assumes a correspondence of inner and outer structures, which are called cognitive concepts and their representations. In his view, this is a reification of the cognitive concepts which in Piaget are still clearly subjective, dependent on cognitive development, and construed actively by the subject. Natural science notoriously offers the temptation of creating a belief in objective givens. But from epistemology we know the change from Newtonian mechanics to Einstein's theory of relativity, a paradigm shift in Kuhn's sense, which has made clear that these quasi-objective laws of natural science are cognitive constructs all the same. Constructivists oppose objectivism by saying that concepts are interpretations which are construed by the individual. Cognitive concepts are dynamic, they undergo a change in the learning process. Instructionalists on the other hand treat cognitive concepts as equal to their formal version, they reify them. Bednar, Cunningham et al (1992) see these two cognitive approaches as irreconcilable and do not think it makes sense to follow instructionalism's usual way of eclectically incorporating new categories into its taxonomies: »We cannot simply add constructivist theory to our smorgasbord of behaviorism and cognitive information processing« (21).

Constructivists accuse instructionalists of falling prey to epistemological objectivism by presenting learning objectives as quasi-objective truths. For constructivists, knowledge is always newly generated and construed. This notion forces them to give up the orientation of instruction towards learning objectives. Learning as process, learning in knowledge communities and context-related learning environments forms the centre of constructivism. This makes it easier to understand that the constructivists' attention is directed to those very higher processes of learning and thought which instructionalists have deliberately left out. Constructivists substitute learning for instruction. It is in this sense that Glaser (1991) deliberately chooses the term »study« instead of instruction (131). The constructivist position is put in more concrete terms by didactic concepts like classroom learning [Bereiter/Scardamalia (1992)], intentional learning [Bereiter/Scardamalia (1989)], cooperative construction of knowledge [Scardamalia/Bereiter (1992); Lesgold/Katz et al (1992)], contextual learning [Tennyson/Elmore et al (1992)] and discovery learning.

Instructionalism's Desperate Last Stand

From Instruction to Learning

The discussion held in Educational Technology in 1991, in which supporters of constructivism were invited to expound their position in a journal edited by instructionalists (Merrill), represents a lucky find for the history of science. This invitation apparently »backfired«, as the subsequent violent reactions of the instructionalists indicate. One could quite clearly see in them, more clearly than the instructionalists would have liked, presumably, that they felt threatened by constructivism. Merrill (1991) demonstrates this most impressively, when he sees himself attacked as »Instructivist Straw Man«, and thinks that his life work is being called into doubt. In Merrill's eyes, the intended intellectual discussion turned into an »insult to those who have dedicated their life to trying to build better instruction«. He retaliates in kind: »We do not subscribe to the tabula rasa straw man of extreme constructivism«. Alarmingly emotional is the reaction, and alarmingly low the methodological level on which the instructionalists Dick (1991), Merrill (1991) and Reigeluth (1991) guide the discussion into this new direction. Small wonder that it was not the instructionalists but the constructivists who later documented this discussion in a reader [Duffy/Jonassen (1992)].

[Situated Cognition, Context Relation and Objectivism

One argument that Merrill (in marked contrast to Ohlsson) does not want to accept at all is the accusation of objectivism. Merrill retorts: »ID2 stands in direct opposition to these extreme constructivist views. We have proposed a syntax for knowledge representation (Jones, Li & Merrill, 1990) that assumes that knowledge, across subject matter areas, can be represented in knowledge frames of three types–entities, activities, and processes« (104). The core of instructionalism is made up of the defined equipment of declarative and procedural knowledge, and the hope to achieve the desired transfer, and thus independence of a knowledge domain (across subject matters), by way of abstraction. It is here, in the abstract knowledge defined in fixed formats, that the reification of cognition lies on which the constructivists' accusation of objectivism is based. And it seems that the very thing which prompted the criticism is also the source of the instructionalists' lack of understanding. ID cannot imagine cognition in any other way than as a scientific format.

Merrill is logically consistent in attacking Brown's, Collins' et al (1989) concept of situated cognition as »extreme and impractical« (53). The reason for avoiding context-related learning situations becomes clear in Merrill's position on Papert's concept of micro worlds, which he pretends to support: »but there is considerable evidence that learning occurs when there is structured guidance available to the students while they learn from a micro world«. The instructionalists' fear of open learning situations is responsible for the retreat to guiding and controlling the learning process: »ID2, in our view, should prescribe the nature of such micro worlds and should prescribe appropriate guidance to accompany such interactive learning environments« [my italics, R.S.]. With the prescription of micro worlds and guiding of the learning processes, the taking over of terms and concepts from constructivism turns into mere metaphor, because the consequences of open problem-solving situations are eliminated in this way. I cannot prescribe motivation, nor can I integrate alternative concepts, which are meant to give room to the learners' own constructions, by prescribing them and providing compulsory guidance on top of that. A situated concept is here turned back into an objectified one. Merrill's desire is to integrate anything which might be regarded as a deficit in his system. Thus he mentions the possibility of providing context relation. But what kind of contextuality can this be, what kind of situated cognition, that can be planned on and determined in advance? The constructivist approach needs social, communicative learning environments, and consequently cannot work with taxonomic classifications of »learning outcomes«. Both approaches might be called instructional design, but they are completely different designs.

Understanding

Merrill (1991) does not personally accept the accusation that instructionalists impart behaviour-oriented skills but no understanding. He claims to want to teach understanding. But the arguments which he uses against this accusation show clearly that he does not even have a hermeneutic concept of understanding: He says that he always intended more than just »rote memorization«; the goals he is aiming at are, among others, »classifying unencountered instances of a concept, using a procedure in a previously unencountered situation, using a principle to make a prediction in a previously unencountered situation, inventing (finding) a new concept or procedure, and discovering a new principle« (52). All his goals can be understood as logical, nomological or general cognitive principles, the overall concept is a deductive-linear process of the application and formulation of knowledge and principles. Merrill confuses understanding with advanced learning objectives. The constructivists' criticism does not state, after all, that instructional design only imparts taxonomically lower levels of learning objectives, they are rather concerned with the acquisition of knowledge by way of interpretation: »Cognitive theories tell us that learning occurs not by recording information but by interpreting it« [Resnick (1989), 2]. The recursiveness of understanding as a self-reflexive process is at any rate outside the instructionalist Merrill's field of vision.

Efficiency Criteria

I have already spoken of the miniaturization of the learning problems chosen for problem-solving by the instructionalists. It becomes understandable why constructivist learning designs seem too complex to instructionalists. But why do the instructionalists infer inefficiency from complexity? Thus Dick (1991) asks, »How inefficient and ineffective is constructivist instruction because it tries to cover too much?« (43), and in Merrill the same argument appears in a variant form: »extreme constructivists propose a methodology that is even more labor intensive, thus insuring that even less effective instruction will be available in the future than is now the case«. As an alternative complexity, Dick proposes instruction as a proportioning of contents and demands: »Designers typically provide learners with only those choices that will insure mastery performance« (44). His model aims at the mastery of skills. His inability to approve the open constructivist approach stems from this: »Constructivists […] show no concern for efficiency, and little apparent concern for certifying the competence level of individual learners«. For instructionalists, constructivism lacks control. Instruction always has its sights trained on the individual as a subject that can be tested, which is really an early capitalist concept. The thought of entrusting the learner with responsibility for his learning process, the »emphasis on learning«, is met with horror by the instructionalists. Constructivists, on the other hand, deliberately put their stakes on this aim: »The student is given much of the responsibility for deciding what to learn and how to learn it« [Winn (1991), 38].

From Instruction to Learning

It seems that the instructionalists have not yet realized this fundamental paradigm shift. Constructivism is not simply concerned with giving the learner »a little more« responsibility, but with the fundamental change from instruction to learning. The teacher is no longer helmsman and policeman in learning, but rather resource and facilitator of the process. The learner is his own control instrument. Giving up responsibility to the learner is not a mere motivation-psychological trick on the part of the almighty teacher in order to manipulate the learner all the better. The learner himself is the focus, as an autopoietic being capable of independent learning.

The instructionalists are vaguely conscious of this paradigm shift, but they cannot reconcile it with their all-dominant concept of learning and teaching as instruction. Dick supposes that the difference might be connected with the term instruction: »Therefore, if instructional designers design instruction, then constructivists are constructing something else. This 'something else' may be a desirable educational intervention, but it does not appear to be instruction« (44). To him, the consequences of the paradigm shift set off visions of horror: »The result is that instruction and performance are de-emphasized by constructivists« (38).

The instructionalists' resistance can in some parts only be understood in sociopsychological terms. Merrill's (1991) laboured distinction of extreme constructivism and moderate constructivism already gives away the desperate and limited perspective of only wanting to discover about constructivism that which corresponds to his own criteria. Merrill's strategy is only too well known in the history of mankind: he splits the enemy into sectarians and reformers, and tries to incorporate the supporters of a supposedly »moderate« constructivism into his own ranks by applauding them: »we have concluded that extreme constructivism does indeed represent an alternative view to Instructional Systems Technology, but that some of the assumptions of a more moderate constructivism are consistent with our views of instructional design« (45). Even more emotional than Merrill's defence is the form of confrontation with the constructivists chosen by Reigeluth (1991) when he brings forward the accusation against Duffy, Jonassen and Cunningham »that the authors advocate an extreme view of constructivism, with an ideological fervor that borders on evangelism, rejecting all other perspectives as 'heresy'« (34). These defence strategies can only be understood psychologically, and are reminiscent of society's treatment of minorities. One of Reigeluth's suspicions may actually be correct: constructivism can only be a truly new and at the same time good pedagogical approach if it is extreme. In that case, however, constructivism is indeed an approach which is dramatically different from ID. And in that case, one may claim quite rightly that the constructivists apostrophized as moderate have basically diluted the approach's radicalness. Apart from this, Reigeluth demonstrates lack of understanding, cavilling and inflexibility in trying the following counter-argument: »If the objective of the group is only to solve the problem at hand, then it is a performance objective, not an instructional objective, and you need performance technology, not educational technology« (35). I leave it to the reader to fathom out the hidden depths of this argument.

In marked contrast to his surface demonstration of a policy of embracing and integration, Merrill (1992) clearly questions the foundations of constructivism when he criticizes situated cognition and insists on the teaching of abstractions: »To insist on context never being separated from use is to deny the teaching of abstractions [...] We agree that the initial instruction must be contextualized, that the learner must experience the abstraction in a variety of contexts and applications; but we emphatically insist that at some point in the instruction these abstractions not only can, but must, be decontextualized if the student is to gain the maximum benefit and ability to transfer generalities and tools to new situations« (106). The meaning of the terms contextualize and decontextualize is telling: Merrill means something like arithmetical problems in text form, not situated cognition. His distinction at best results in the strategy 'divide et impera', as if to say: there may be some areas in which one may contextualize, but there are others in which abstraction is imperative, a distinction also introduced by Spiro, Feltovich et al (1991b), (25), albeit for a different reason, which Reigeluth (1991) immediately and thankfully accepts as a moderate trait (36).

Conversely, one of Merrill's main accusations against constructivism is the fact that it rejects the »prespecification of knowledge« which is essential to instruction: »But to deny simplification, to deny isolating a generality from context, to insist on all instruction occurring in the context of use, is to deny some of the great advantages of learning from instruction versus learning only from experience« (105). Is that indeed a decisive shortcoming of constructivism, as Merrill supposes? Constructivism does not claim, after all, that there is no abstraction in thinking, that generalization never happens.[12] The decisive difference lies in the fact that knowledge is construed and reflected ad hoc within the process and cannot be stored once and for all. Clancey (1992) attacks the model of human memory as storage device for schemata, which is shared by instructionalism and information theory. To him, this seems to be the source of the notion of the representations' identity with the internal concepts, which marks the cognitivists' objectivism. But the instructionalists' claim that there is something like a trainable transfer which works by generalizing abstractions also stands and falls by this very notion.

And there is something else in which Merrill gives false change: the term of discovery learning. It can mean anything, derivation, inference, generalization, anything but discovery. DiSessa's (1992) criticism is directed towards this reinterpretation: »Yet so much that is called discovery learning falls within a paradigm where students are sat down in front of a narrowly focused system, which

12. It must not be overlooked that the question of how constructivism deals with organized learning processes, which after all also occur in learning programs in a codified form, seems to mark a contradiction. But it only seems to do so, as Winn (1991) observes: »while instructional design by constructivists may seem to be a contradiction in terms, there is still a lot of designing to do« (39); cf. also Clancey's (1992) observations on this question, who emphasizes how much the design of concrete learning situations and learning environments is at the heart of the constructivists' interest.

is constrained to particular operations aimed at having the student discover some particular law or fact […] This does violence to my sense of authentic-feeling activities for children, and to the epistemological problems I believe some version of discovery learning is well-adapted to solve« (23).

Cognitive Flexibility Theory

In his fictitious Socratic dialogue, Cunningham (1992) has the character of Sagredo postulate that skills are not independent quantities, but abilities acquired in practical action, and thus context-related abilities. Therefore, this »situated knowledge« should also be learned in contextualized form, in a stimulating environment offering a multitude of contents and meanings, in so-called »authentic environments«. The opponent Simplicio in Cunningham's dialogue has the task of asking the critical questions the instructionalists have for constructivism. Such critical questions are: Is constructivist learning only suitable for advanced learners? Is it only suited to learning on more complex program levels? Or is constructivist learning specifically suited to learning in »ill-structured domains«, a hypothesis put forward by Spiro, Coulson et al (1988)? Thus Cunningham makes his Simplicio say provocatively: »And I have become convinced more than ever that constructivism is simply a label for fuzzy, unscientific thinking«. By this, Cunningham apparently alludes to the eclectic constructivism of the so-called » cognitive flexibility theory « by Spiro, Feltovich et al (1992), who restrict constructivist learning to complex, so-called »ill-structured domains«. Spiro, Feltovich et al describe their hypothesis as follows: »An ill-structured knowledge domain is one in which the following two properties hold: (a) each case or example of knowledge application typically involves the simultaneous interactive involvement of multiple, wide-application conceptual structures (multiple schemas, perspectives, organizational principles, and so on), each of which is individually complex (i.e. the domain involves concept- and case-complexity), and (b) the pattern of conceptual incidence and interaction varies substantially across cases nominally of the same type (i.e. the domain involves across-case irregularity)« (60). They regard subjects like medicine, history and literary studies as exemplary for their distinction.

The so-called cognitive flexibility theory has the following sentence at its core: »A central claim of Cognitive Flexibility Theory is that revisiting the same material, at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives is essential for attaining the goals of advanced knowledge acquisition« (68). This statement is not false, but neither is it new – and why should it represent a theory? The teacher's old wise saying that repetition with different examples and in a different form is useful is known to any communication scientist by the name of redundancy. One really wonders why Spiro et al are determined to join the constructivist phalanx with this idea.

Another assumption of Spiro et al is the distinction between beginners' learning and advanced learning: they assume, as traditional school curricula do, that there are different goals for beginners, and that beginners can therefore be treated more simply and directly. With beginners, all that matters is a superficial consciousness of the basic concepts, whereas with advanced learners mastery of the complexity and transfer must be achieved. It becomes evident here, however, that the conventional image of the curriculum is the concept's real foundation, and that it is not in turn the hypothesis of cognitive flexibility which plausibly legitimizes a distinction of learning phases.

The problem on which constructivists stumble in this discussion is the question whether the situations of constructivism, so rich in content and meaning, would not overtax inexperienced learners. The answer to this question distinguishes genuine constructivists from those who do not have such a firm grasp. With the latter, the old-style pedagogues resurface and try to suggest simplifications, to integrate drill & practice, and to insert specific instruction in basic knowledge. Jonassen (1992), for example, immediately expands Spiro's et al idea into a curriculum model: in the traditional manner, he distinguishes three phases: beginners, advanced learners and experts. To the first phase, he assigns well-structured knowledge domains and practice & drill as the proper form of learning, to the second phase he assigns ill-structured knowledge domains and apprenticeship and coaching as methods, and observes: »Constructivist learning environments are most appropriate for the second stage, advanced knowledge acquisition« (143). Fosnot replies: »In my mind, he has missed the main point of constructivism. Learners are always making meaning, no matter what level of understanding they are on […] To assume the learner is a blank slate until presented with information, and to characterize experiences or tasks separate from the learner's meaning of them, is objectivistic–a perspective which in the first chapter Jonassen (& Duffy) so radically opposed!« (172) The alliance of Duffy and Jonassen seems a brittle one. Irrespective of the criticism, Jonassen repeats this curriculum notion: »designers and educators must consider the context in which constructivist learning should take place. Otherwise, we risk falling into the pit that is filled with so many other panaceas for learning« [Jonassen/Mayes et al (1993), 231]. Why should one have to decide where constructivism is to take place and where not? Constructivism is misunderstood here by Jonassen et al as one teaching method among others, comparable to teacher presentation, discovery learning and role play. This attitude implies a panopticon at one's disposal, parts of which are then distributed, as in a buffet lunch. Jonassen's external perspective on constructivism objectifies constructivist learning situations as objects of exchange: »We believe that constructivistic learning environments […] most reliably support the advanced knowledge acquisition stage of learning. This stage of knowledge acquisition is most consistently required in university courses«. Constructivist learning is thus restricted to university! It is turned into a kind of research learning or study project for advanced learners. But constructivism is not a teaching method in the first place but rather an attitude towards learning, and it cannot simply be abandoned when dealing with primary pupils. On the contrary, the collected examples from the Papert group show that they are especially concerned with learning of younger children [Harel/Papert 1991].

Fosnot (1992) probably offers the most consistent view of constructivism. She even has to state that constructivists are not always their own best attorneys. Fosnot's analysis can be called consistent because she once again backs up the constructivist exchange formula, which have been degraded to metaphors in the meantime, with the methodological foundation they had been given in Piaget, and proves that both the constructivists represented in the volume, like Jonassen (1991), and the instructionalists like Merrill argue with self-contradictory statements. Fosnot also tackles the hypothesis of Spiro et al: »Constructivism is not a theory to explain only complex, ill-structured domains; it is a theory how learners make meaning, period!« (172) In her view, the distinction of basic knowledge and complex problem-solving environments is artificial: each action generates meaning, each action is an interpretative act, be it incidental or intentional, conscious or unconscious. The instructionalists have tried to channel this act, the constructivists have tried to accept it and go on from there.

Transfer as a Touchstone for Instructional Design

The importance of the search for teachable, general learning skills, skills that work independent of the concrete, actual subject matter, has always been an important question in education science: »Educational research has long addressed this question under the rubric of transfer. In a sense, transfer is the holy grail of educators–something we are ever in search of« [Resnick (1989), 8].

The particularization of learning in skills under the paradigm of instructionalism only makes sense if one still insists on the demand for transfer of learning and the acquired cognitive skills. But Clark (1992), for example, utters criticism in that context, especially with regard to studies trying to prove the transfer effect of learning to program: »Given the weight of evidence, the best advice one might derive from a survey of the programming and transfer research is that we should reduce our investment of scarce research funds on transfer studies of programming. It appears that computer programming is no more related to domain-general transfer than the learning of any other analytic problem solving activity« (268). The meagre result may be due to the presently existing transfer theories, according to Clark (282). But following Elshout (1992) one can generally say that the training of formal principles is no guarantee for transfer: »formal logical training does not transfer to the task in its symbolic, decontextualized form« (12). Intra-field transfer is to be aimed at, inter-field transfer rather improbable [Oliveira (1992), 9]. The role of transfer from a constructivist perspective is critically examined by Prenzel and Mandl (1993). Pea (1988) offers a comprehensive overview over transfer concepts from Thorndike to constructivism.

Does transfer present a problem for constructivism as well? Is transfer merely a question of empirical proof, as Tobias (1992) assumes: »Fortunately, these are empirical questions and they should be investigated« (206). The problem of transfer is not all suited to decide the trench war between instructional design and constructivism. Up to now, no educational school has been able to prove transfer, let alone the efficiency of transfer in relation to teaching methods. Transfer is a quantity in the educational process that will probably never be empirically verifiable. Clancey (1992) gives detailed comments on the transfer problem from a constructivist point of view. The term transfer can only be understood from the perspective of objectivism, he says, it suggests an inadequate view of cognition as a tool, as if one could simply apply existing knowledge or ready-made cognitive concepts to other situations. Transfer approaches all start out from the assumption that there is something like a higher general matter, which one must imagine as independent of context, and which is called metacognition, analogous thinking, or simply abstraction [Merrill (1991)].

One can put Clancey's interpretation of transfer into even sharper focus if one looks at the function of transfer from the sociological and anthropological point of view, as an expression of cultural transmission in societies: »The concept of cultural uniformity reflects functionalist assumptions about society as a consensual order, and cultural transmission as a process of homogeneous cultural reproduction across generations« [Lave (1988), 10]. Lave offers a thorough analysis of traditional transfer concepts and experiments (23ff.), and comes to the conclusion that all experiments »dissociate cognition from its contexts, and help to account for the absence of theorizing about experiments as social situations and cognition as socially situated activity« (43). Lave's analysis of mathematical concepts in everyday situations, e.g. shopping (45ff.), demonstrates the high variation of arithmetical concepts in practical applications, and its dependency on objects and situations. The situation of cognition in everyday situations demanding problem-solving yields even more negative results for the validity of the transfer concept. What is interesting about Lave's studies is that she chooses mathematics of all subjects, an area that has always been supposed to have stable concepts and a high transfer degree.

In exact opposition to instructionalism, which relies on abstraction or generalization for transfer, constructivism trusts that context relation will substitute transfer. On this note, Mandl and Hron (1990) criticize methods in which no 'experience context which is close to life' can be established: »This makes the transfer of acquired knowledge to other fields seem doubtful« (2).

CHAPTER 6 Intelligent Tutoring Systems

Agents, Robots, Knowbots, Microbots, Mobots and Other Smart Dwarfs

This chapter is the first in which we meet programs that »think«, »talk« and »understand« language. Let me take the opportunity to discuss, by way of introduction, notions of »intelligent« computers which perhaps have been influenced by the images of the talking being HAL 9000 in Stanley Kubrick's movie 2001 or the funny robot R2D2 in Star Wars. Joseph Weizenbaum's ELIZA (1966), on the other hand, is generally only known to computer users, a program which imitated conversations with an artificial therapist – or rather parodied them, as Weizenbaum later claimed.[13] Whoever was fascinated by the movie character R2D2 may join in Perelman's (1992) speculations about further development of anthropomorphic computers (29):

»Humanish androids need to see and feel their environment, as well as to be able to move around in it and manipulate things, as robots can do. Then they need to be able to think not only with great computational power but with at least the crucial animallike ability to learn from their experience of the world. Finally, to have some android sociability, advanced machines should be able to communicate in a natural way with humans, in conversation. In reality, progress in all these key areas is coming rapidly […] The humanlike level of performance will require only that computer power continue to advance at the same rate over the next few decades as it has over the past half century«.

Is Perelman right in assuming that this development advances rapidly and is only dependent on technical progress? In the event of the development of anthropomorphic computers indeed taking place within the next decade, are we allowed to simply drop the philosophical issue whether there is any sense in having humanlike computers in the face of such rapid technological progress? Perelman considers this question closed: »But it is not necessary to settle the deep philosophical questions about whether a machine could ever be 'equivalent' to a human being to recognize that, for economic purposes, ever-smarter machines already do and increasingly will perform roles that once only could

13. Weizenbaum (1977). In his 1966 essay, however, the parody does not make itself felt. Apart from a number of technical details the essay offers only one remark relating to the program's contents: »At this writing, the only serious ELIZA scripts which exist are some which cause ELIZA to respond roughly as would certain psychotherapists (Rogerians)« (42).

be performed by a human« (30). They will be able to think and talk, those androids, and probably also be able to see and touch, but they will never be able to have real feelings. They will always lack the affective-motivational component one would expect from a 'natural' interface. And the notion of having them simulate feelings or feign empathy [Lepper/Chabay (1988)] possibly marks the decisive borderline which should not be crossed. Mandl and Hron (1990) thus fear that an anthropomorphization of computers could lead to an »internalization of the conditions of the machine-controlled dialogue« (30ff).

Much more sober and geared towards the daily work of humans with computers, although no less exciting, is the vision Apple Computer has sketched in the video *Knowledge Navigator*, described by Sculley (1989) in a presentation, of a multimedia, talking, thinking, planning computer which makes decisions by itself. Negroponte (1995) applauds his vision: »He [i.e. Sculley, R.S.] wanted to illustrate an interface of the future, beyond mice and menus. He did an excellent job« (92). The image of a computer who is a perfect personal assistant and who gathers a lot of knowledge about his owner, combined with the notion that the owner carries it everywhere (ubiquitous computing), has already led some critics to ask absurd questions like: »What happens when the owner dies? Will the computer be buried as well?« [Stonier (1991)]

Laurel's (1990) attempts to have agents appear on the screen as visual representations of human personalities are probably triggered by such notions or similar concepts: »An interface agent can be defined as a character, enacted by the computer, who acts on behalf of the user in a virtual (computer-based) environment. Interface agents draw their strength from the naturalness of the living-organism metaphor in terms of both cognitive accessibility [im Original falsch getrennt] and communication style« (356). Laurel discusses psychological resistance to such agents. It is obvious that the use of an agent must be profitable, e.g. in repetitive tasks, and that it must be more effective to instruct the agent than to carry out the task oneself. Laurel's position is that the agent should be given a human appearance: »Anthropomorphizing interface agents is appropriate for both psychological and functional reasons« (358). Anthropomorphism corresponds to the natural needs of man: »Anthropomorphism is not the same thing as relating to other people, but it is rather the application of a metaphor with all its concomitant selectivity«. An agent according to Laurel's concept is, however, not a homunculus, but a caricature: »When we anthropomorphize a machine or an animal, we do not impute human personality in all its subtle complexity; we paint with bold strokes«. The agent offers dynamically calculated ways of navigation to the user, without reducing the multimedia system to a KIOSK system. Among the tasks of an agent, Laurel (360) counts the following:

TAB. 2
Functions of Agents according to Laurel

Information	**Work**	**Learning**	**Entertainment**
Navigation and Browsing	Reminding	Coaching	Playing against
Information Retrieval	Programming	Tutoring	Playing with
Sorting and Organizing	Scheduling	Providing Help	Performing
Filtering	Advising		

Isbister and Layton (1995) differentiate function descriptors, communication abilities, delegation of control to the agent, confidence in the agent, and the agent's appearance and personality in interface agents. Based on Piaget's theory of cognitive development stages, they discuss, the problem which agents correspond to which development stages, and distinguish between the naive agent of the sensori-motor phase, the knowledgeable agent of the pre-operational phase, and the autonomous agent of the concrete and formal operational phases. With regard to the debate about anthropomorphism, they argue that in discussion the agents' functionality should be detached from the question of the anthropomorphization of their appearance (79/80). Schmidt (1995) classifies agents in computer-aided communication in higher education according to their type of knowledge representation (reactive, non-deliberative vs. reflective, deliberative agents), to capabilities (technical, cognitive, and social abilities, also whether they are intelligent or not), and according to qualities (situated, autonomous, rational, intelligent, social) [144; s. a. Sundermeyer (1993) and Müller (1993)].

Setting aside for a moment the spectacular aspects of these android artificial machines and their personification in Laurel's work, there remains one feature which information science currently discusses under the heading of software agents or personal assistants – a software which is able to draw conclusions from the user's activities and preferences and to make autonomous decisions. There is nothing spectacular about these agents, we may regard them with Negroponte as simply an additional functionality of the user interface: »What HAL and the Knowledge Navigator have in common is that they exhibit intelligence to such a degree that the physical interface itself almost goes away. Therein lies the secret to interface design: make it go away« (92).

Negroponte rightly points out that what is exciting about these visions is not the androids' visual appearance but the interface problem. Software agents can do their work imperceptibly and inconspicuously in the background as an important part of the computer's functionality. In this sense they »humanize« the props, so-called user interfaces, which allow us to communicate with the computer today. An example of how agents might be usefully employed is the *NewsPeek* program at M.I.T., which compiles a personal newspaper for the user [Brand (1988)]. Other examples, which immediately clarify the idea, are the agents for booking flights and travels invented by the developers of the

MagicCap-interface. Shneiderman (1986) points to the development history of the robots, which has shown, that robots have gained functionality since developers have increasingly dropped their anthropomorphic elements: »Sharpening the boundaries between people and computers will lead to a clearer recognition of computer powers and human reason […] Rapid progress will occur when designers accept that human-human Communication is a poor model for human-computer interaction« (434). According to Laurel an agent can only then be successful, when he is able to adapt to the user (responsive). Adaptivity runs the risk of incorrect inference. But: »The risk of incorrect inference can be mitigated by a variety of strategies for disambiguation, including dialogue, user modeling, and the creation of redundancy through the use of multiple input channels« (361).

An intermediate stage in this debate is marked by the discussion between Susan Brennan, Brenda Laurel and Ben Shneiderman at the CHI'92 Conference. The linguist Brennan stresses that there are circumstances which can be more easily expressed through language than through a mouse-oriented iconic interface. Her position is best characterized by referring to a statement published two years earlier: »But the dichotomy between direct manipulation and conversation is a false one« [Brennan (1990), 393]. The former drama theorist Laurel proposes the thesis that the orthodoxy of direct manipulation prevents the use of anthropomorphic or animist representations for complex agents. Shneiderman points out the history of design which had demonstrated that any technology goes through a phase of immaturity in which human and animal models were used as metaphors. These representations had later proved to be an obstacle for the development of more powerful and simple tools. He alludes to technologies which used to have a natural language interface and have been removed from the market by now. Historical figures in multimedia applications, like the travel guides described by Laurel (1990), are however expressly excluded from this criticism: »I am sympathetic to human faces appearing onscreen if they are to represent human beings. My objection is when the computer is portrayed as a human; such misrepresentations are deceptive, counterproductive, and morally offensive to me« (69).

Software agents and androids are concepts from the branch of information science known as artificial intelligence [Minsky (1994)]. Whether one should have expectations corresponding to Perelman's of artificial intelligence is doubtful in my opinion. Today's state of that information science branch, which views intelligence mostly as an application of predicate logic[14], is not exactly likely, at any rate, to support such spectacular visions: »The most sophisticated languages claim only second-order predicate calculus capability. As long as this remains true, we must either develop classical logic algorithms for model, epistemic, deontic, and counterfactual reasoning; or we must aban-

14. see Minsky's (1981) and (1992) criticism of the logical approach of AI.

don the idea of holding normal conversations with computers« [Woodward (1991)]. The lack of a modal logic and heuristic procedures on current computers leads to a restricted simulation of human reasoning, and produces a result which can somewhat rudely be summarized like this: »Artificially intelligent computers, as they now exist, represent a 'cognition' that if evidenced in a human would probably be classified clinically as schizoid, retarded, lacking affect« [Nix (1990), 162]. There are also prominent voices expressing general doubt regarding the developing ability of current systems: »I think that this whole artificial intelligence movement is more of an ideology than research [...] I don't know whether I would invest my last million in this area or rather not«.[15]

A special aspect of anthropomorphizing the computer is addressed with the question whether the modern user interfaces should enable the user to address the computer in natural language. Apple has already shipped such a speech recognition technology for the Macintosh with System 7.5. The embarrassment which the user may feel when addressing the computer is perhaps only temporary, a question of getting used to, although one could just as easily share Hanne's (1992) suspicion that mimicry may not be a suitable paradigm for the design of user interfaces: »The most natural means of communication between people is not necessarily the most 'natural' one between human and computer« (160). The computer is not a natural being, it only has artificial language. It seems more practical and sensible to me to communicate with this artificial language by way of direct manipulation of objects and perhaps conventionalized gestures rather than by way of natural language. Negroponte (1995) is of a different opinion here. He is convinced that in twenty years' time »voice will be your primary channel of communication between you and your computer interface« (148).

Intelligent Tutoring: What is ITS?

Parallel to courseware and instructional design, intelligent tutoring systems (ITS) were developed. In general, AI in CAI is attributed to Carbonell [Wenger (1987)]. Carbonell's prototype SCHOLAR was intended for learning South American geography. This happened in the form of a so-called Socratic dialogue of an artificial »tutor« with the student. It is noteworthy that the part of the program which analysed the student responses in SCHOLAR and developed its tutorial steps from them, the inference engine, is already designed in such a way that its mechanisms worked independent of the current knowledge domain.

15. Weizenbaum interview in: Fascination 9, Winter 1994/95, ed. FAST, 24.

An ITS consists of a modelling of a knowledge domain (domain model), a model of the student (student model), modelled educational strategies (tutor model), and a component for the communication of the program with the student (interface) [Barr/Feigenbaum (1982), 229ff.; Sleeman/Brown (1982); Spada/Opwis (1985)]. These aspects will be briefly discussed in the following. The reader will find comprehensive discussions of both formal and conceptual aspects of tutor models in Dillenbourg and Self (1992a), as well as in Anderson and Boyle et al (1985b). The theoretical problems of machine tutors are treated in detail by Woolf (1987). Clancey (1988b) points out the special aspect of the difference between quantitative and qualitative models.

Knowledge Domain or Expert Model

The »knowledge domain« defines an expert's knowledge in an area of knowledge. It is also called expert model for that reason. It consists of declarative and procedural knowledge [Winograd (1975)], and is organized in the form of lists, knowledge structure diagrams, or rules.

Declarative knowledge defines terms from the knowledge domain (e.g. force, speed, light etc.) by their attributes, and defines the relationship of the terms, often in the form of frames with inheritance. Procedural knowledge consists of arguments or rules which are intended to help in solving problems. Occasionally, heuristic knowledge is distinguished apart from declarative and procedural knowledge. Heuristic knowledge consists of the experience and problem-solving knowledge of experts which is not confined to particular contents; it consists of acting advice for transformations which the student can apply to the learning matter, or for operations by which problem-solving processes can be broken down into manageable activities, e.g. `Solve equations in …`, `Apply example to …`, `Identify all objects in …`, `Find all unknowns in …` Heuristic knowledge is necessary so that the tutor is able to guide the student in his learning processes and problem-solving behaviour.

There are basically two models for the design of the knowledge domain: the »black box model« and the »glass box model«. With the black box model there is no claim of reproducing human intelligence. The program SOPHIE I by Brown, Burton et al (1974) [s.a. Brown, Burton et al (1975)] is considered an example of the black box model. In the glass box model, the knowledge domain is modelled in the form of an expert system and makes a claim to reproduce the problem-solving behaviour of human experts [Goldstein/Papert (1977)]. The glass box model is called by that name because it is »transparent«, i.e. because one can observe its working method.

In advanced models, knowledge is defined as a semantic net. The net consists of nodes with patterns and typed relations [Jonassen (1992a); Norman/Gentner et al (1976)]. The subject matter of the knowledge base must at least be suited to conclusion-making and problem-solving. In Jonassen (1992a), the expert model also contains rules for the optimal sequencing of knowledge, in order to make it more suited to making suggestions about the order of learning matter to the student.

Student Model or Diagnosis Model

The model for the learner is called »student model«. Self (1992) points out that he prefers the term 'learner modelling', »as it carries no implication that the learner has some official status as student and it is more optimistic!« (17) The student model is also called diagnosis model, because the reproduction of the learner is meant to serve a diagnosis of the learning process.

A student model[16] must be able to define the learner's current knowledge at any time in the course of the program. The student model is also made up of declarative and procedural knowledge [Anderson (1983)]. In the declarative part of knowledge, there may be interrelations (interconnections, structural knowledge). One distinguishes two kinds of student model in principle: Student models can try to determine the student's knowledge as a subset of the expert model (subset model), or as a deviation from the expert model or an expert's performance in the same situations (deviation model). In other words, diagnosis has two possibilities:

- The parts of the expert knowledge which the student has done are ticked off. The subset model is also called »overlay model« [Carr/Goldstein (1977)], if it also contains rules for conditions of learning.
- The student's answers are analysed, and it is concluded from the answers by way of inference what has been understood, with the inferences only covering the student's knowledge, not »explaining« his learning behaviour. The deviation model or difference model is also called »buggy model« [Brown/Burton (1978)]. Kass (1989) refers to the difference model as »perturbation model«. In models of error analysis, enumerative and generative systems of error analysis are distinguished, with the latter based on theories of knowledge acquisition.

The diagnostic ability of tutor models is content-oriented, not psychological. The overlay model has a particular weakness: It cannot recognize whether the learner's knowledge differs from that of the expert because the learner does not have that knowledge, or because he follows different strategies from the expert. The difference model comes a bit closer to this, although in the last

16. Psillos/Koumaras (1992), 86ff.; a solid overview over student models in particular is offered in Elsom-Cook (1993); s.a. Brokken/Been (1993); McTear (1993); Benyon/Murray (1993).

analysis it can also merely assume lack of knowledge if there are differences between expert and learner. This sounds very complicated but is quite simple really. Elsom-Cook's criticism is not without good reason: »These approaches both imply a very simplistic model of the learning process (not far removed from rote learning), which takes no account of the rich range of learning styles and capabilities for which there is psychological evidence« (172).

From an analysis of student models, Self (1988) determines 20 functions of student models which he subdivides into six groups:

corrective function — the system must be able to correct incorrect knowledge of the student, find the mistake by backtracking the problem-solving process, initiate correction, generate an example and present it, follow the learner's train of thought step by step and find the source of the misunderstanding;

elaborating function — the system must intervene if the learner's knowledge is correct but incomplete; the system compares the expert model with the learner's current state of knowledge and suggests actions;

strategic function — analysis of the learner can lead to a change of the methodical level or the provision of other learning strategies; the system can take the entire learning process onto a higher level;

diagnostic function — the model is supposed to find out the learner's ideas; the system can analyse the student model by itself;

predictive function — the system must be able to simulate the learner in the form of a model in order to be able to find out into which direction the learner's learning processes might lead; the system can use and simulate the student model in order to make predictions about the learner's behaviour;

evaluative function — the system must be able to reconstruct the learner's learning process from the recorded learning history.

What seems to have been mostly developed are diagnosis models in the sense of bug recognition [Stevens/Collins et al (1982); Ohlsson/Langley (1988)]. For bug diagnosis models, libraries with possible bugs must be created on top of the knowledge for the knowledge domain. In order to save themselves the trouble of this arduous and work-intensive step, Ohlsson and Langley (1988) have developed a program that registers bugs in the course of the program and then machine learns them. But: »Neither the bug library technique nor the machine learning approach is currently used extensively in instructional computing systems« [Ohlsson (1993)].

Burton (1982) gives a detailed description of an intelligent tutor's diagnosis process for the analysis of arithmetical mistakes in subtraction. The problem seems to be not only in foreseeing the worst mistakes of learners, but rather that those mistakes only seldom occur in pure form and more often in mixed forms, so-called compound bugs, for which compound hypotheses must be proposed. For this reason, a major part of the designers of such diagnosis models activities' consists of developing heuristics for the reduction of search space, and thus limiting the initial set of hypotheses. The spontaneous, non-systematic mistakes of learners, which cannot and are not supposed to be explained by the system, present an interesting methodological problem, as do other inconsistencies in the system which occur in the process of hypothesis generation, and are described as »noise« in theory (a term adapted from radio technology). The bug diagnosis methods of the student model are interesting in this context. They assume that one should replace faulty concepts with expert concepts. This substitution hypothesis betrays the reification to which IT designers subject cognition, and serves as a reminder of the general criticism that was already levelled against the correspondence hypothesis.

Serious gaps in student models lie in the area of variables of learning behaviour. One would wish for systems, for example, which could evaluate the psychological plausibility of a solution or mistake, but »there are disappointingly few psychological principles that can be used for this purpose« [Ohlsson/Langley (1988), 50]. The individual learning styles and strategies researched by the psychology of learning also do not play any or only play a very small role in student models.

Ohlsson (1993) stresses the enormous effort that goes into the development of an ITS, and the cost that arises. Most authors of prototypes name a developing time of about 4 years. And since there is a suspicion that the bugs determined for ITS may not be stable, the work must be done over and over again for new generations of pupils and students (209).

Although student model and user model basically only stress two different aspects of the same learning and interacting agent, the categories of agents' intentions (plans, aims, strategies) which are pursued in action theory or interaction theory approaches for the development of user models [Kobsa/Wahlster (1989)] are only seldom applied to student models of tutorial systems. An exception is the ITS PROUST by Johnson and Soloway (1987). This is one of the reasons for Kass (1989) to promote increased cooperation in precisely this area of intersection.

Tutor Model or Educational Model

The tutor model contains knowledge and prescriptions for the presentation of learning materials following the question pattern »what, when, how?« The tutor model simulates the decision behaviour of a teacher, a decision process referring to pedagogical intervention, and generates appropriate instructions, on the basis of the differences between expert model and student model. Two tutorial methods or strategies dominate: the Socratic dialogue, and »coaching«.

The method of the Socratic dialogue puts questions to the learner in order to encourage him to analyse his own mistakes. The coaching method prefers learning environments, similar to those in CBT programs, with problems and activities for exercising skills or trying out solutions to problems, and reacts to learning behaviour in these situations with tips and advice. On the whole, one can say that the tutor model follows rather the instructional approach than the concept of discovery learning or the »cognitive tool« approach which sees the computer as a tool in the construction of cognitive concepts.

FIG. 16
Exercise from an ITS on Arithmetic

```
    Problem #1
    25 + 17 = 33.            That is not correct
                             Try again with steps


20 + 10 = 30
5 + 7 = 12
30 + 12 = 42

The final answer is:
         25 + 17 = 42         O.K.


                                       -- press Return --
```

Something that still does not get enough attention in current tutor models is e.g. the everyday reasoning of the teacher, his assumptions about the learning process of the pupil or student, and his knowledge of the situation structure and rules of interaction, the »grammar of interaction«. It is here that the most serious weaknesses lie, with the result that the currently known tutor models mostly seem rather schematic to learners.

One might assume that the designing of student models and tutor models would and should finally serve the aim of letting the learner participate in the design of such systems from the very beginning. This assumption is erroneous, however. The designers of tutorial models do not start out from a participation concept, but rather design the learners. The students designed as abstracts cannot feel incorporated, but stand opposite the system as external beings. This is also due to the didactic function of the tutor, who is supposed to work out learning schedules and suggest exercises: »the assumption of a given task and given expertise puts students in a passive role with respect to finding their own problems and developing their own expertise« [Bredo (1993), 37]. The passive role assigned to the students can lead to this nicely put result: »students become book smart and practically stupid«.

Interface or Communication Model

An ITS is meant to analyse the process of current knowledge acquisition, and to be able to draw conclusions from this and generate instructions which are suited to reducing the discrepancy between expert and novice. An ITS is supposedly »intelligent« because of its communication model, which is supposed to enable the system to react flexibly and adaptively to the learning process, flexible in the arrangement of learning matter and adaptive with regard to the state of knowledge and the cognitive processing achievement of the learner. One must not, however, equate this adaptation with »understanding«, a skill of teachers. The interaction between learner and system can assume different forms:

- The system puts questions to the learner, guides him by way of the questions, and tries to determine mistakes from his answers (the so-called »Socratic dialogue«)
- The system lets the learner work for himself and waits until it is asked for help (»coaching«)
- The system is active itself, invites the learner to select information and deducts deviations from the expert model from the selection (»learning by doing«)
- The tutor remains in the background and only gives helpful advice now and then (»learning while doing«).

Tutors can realize either directive or non-directive behaviour. A mixture of interaction styles has not been realized as yet according to Elsom-Cook [(1988), 166]. Many systems seem to implement the strategies only superficially. Thus Elsom-Cook criticizes the models trying to implement the Socratic dialogue, for example: »Although these systems have the surface form of such a dialogue, it is by no means always the case that the dialogue is truly Socratic« (166). Mandl and Hron (1990), too, distinguish systems that have guided learning or instruction as their aim, such as the *LISP Tutor* by Anderson and Reiser (1985), from those systems that are modelled on a microworld concept, and whose aim can be seen as discovery learning, such as *Smithtown* by Shute, Glaser et al (1989). The instructional concept knows lessons and a systematic structuring of instruction, mediates the learning objectives to the learner, suggests exercises, gives instructions and presents explanations. The microworld concept is more free, it presents an interactive environment in which something is to be discovered. The concept calls for formation of hypotheses from the learner and requires him to experiment with these hypotheses.

Kearsley (1987) distinguishes five types of interfaces for IT systems: Socratic dialogue, coaching, debugging, the microworld, and explanatory expert systems (5/6). Elsom-Cook shows tutorial systems along a continuum that reaches from complete control of the dialogue style to complete freedom of learning.

An ITS simulates the natural language behaviour of the teacher [Mandl/Hron (1990), 21]. One may put it cautiously as Mandl and Hron do: »The system's interaction with the learner should approach a natural language dialogue«. Or one can put it more absolutely, and define natural language access as a necessary feature of a tutorial system [Spada/Opwis (1985)]. Natural language access could only partly be realized in the years in which such systems were created, namely in the form of typed input and output on the screen. The quasi-natural form of the sentences was also difficult to program.

ITS Dialogue from the GEO Tutor

** Let's talk about Western Canada
Fine. What is the capital of British-Columbia?

** Vancouver.
No, the capital of British-Columbia is Victoria.

Where is Victoria situated?
** Let's discuss Banff.

I do not know Banff. Is Banff the name of a place?
** Yes. It is a town.

Where is Banff located?
** In the Rocky Mountains.

Is Banff in British-Columbia or in Alberta?
** In B.C.

What is the population of Banff?
** 5000.

What other towns are near Banff?
** Tell me about Victoria.

Victoria is situated on Vancouver Island. It is the second largest city in British-Columbia. What else would you like to know?
** What is its population?
[Duchastel (1992), 73ff.]

Systems which allow an oral addressing of the computer and output in synthetically generated speech are almost completed today. And linguistic research on the grammar and semantics of language is much more advanced now. Nevertheless – or maybe because of this – one may and should bring up the question again today, whether the quasi-natural dialogue really plays such a decisive part in the realization of an electronic tutor, from a psychological, didactic, and even a political point of view. I share Woolf's (1987) opinion in this regard: »Effective communication with a student does not mean natural language understanding or generation [...] Rather, effective communication requires looking beyond the words that are spoken and determining what the tutor and student should be communicating about« (241). Natural language dialogue is a possible addition to a tutorial system, but not a necessary one.

Ideally, the arguments for choosing an ITS refer to aims like processes of learning on a higher level, critical reasoning, analysis, argumentation, decision-making behaviour, problem-solving, even self-reflection [Hedley/Ellsworth (1993)]. But occasionally, even with regard to explorative learning environments, traditional educational reasons are cited as well, which we have already come to know with courseware, instructional design and the discussion of student control: »Indeed, the unobtrusive interventions of a coaching component can save the student from problems typical of unguided learning such as stagnating, floundering excessively, or overlooking learning opportunities« [Wenger (1987), 425]. In the foreground of intelligent tutorial systems is the aim of individualization, as in Programmed Instruction: »One of the most obvious advantages of an ITS is simply achieving a more favorable teacher-student ratio« [Burns/Parlett (1991), 4]. Other than Programmed Instruction, however, ITS is supposed to achieve individualization by analysing the learner and adapting its tutor to his current state of knowledge in an »intelligent« way. Burns and Parlett foresee a rosy future, »The outlook for ITSs is bright«, although it is clear to them that there is still a long way to go until then: »Intelligent tutoring systems are tools for the 21st century« (10).

Not all tutorial systems attach importance to fully developing all four components. Some models content themselves with lists of the skills to be learned, others restrict themselves to a process model of beginners' learning processes in the respective knowledge domain [Littman/Soloway (1988)]. Some models restrict themselves to declarative knowledge, others to procedural knowledge: »most systems focus on the development of only a single component of what would constitute a fully usable system« [Kearsley (1987), 18]. One can therefore view many of the well-known systems as prototypes for research and development, which could not serve as programs for actual instruction: »Some systems do not even have the functions for representing one or two instructional components. For example, PROUST [...] and STEAMER [...] do not have functions to provide direct instruction« (21).

Learning in the sense of ITS, like Programmed Instruction, is based on a concept of behaviour, the domain model is a model of concepts in the sense of behavioural objectives, the student model is a model of the student's behavioural sequences. In contrast to behaviourism, an attempt is made, however, to define cognitive concepts for the domain. But the whole design of ITS cannot avoid an operationalization of these concepts as behavioural objectives, if a comparison of student model and knowledge domain are to be possible. An ITS is a functional system that is meant to optimize the relation between initial state, objective, and final state. Educational or psychological theories have a quite different methodological status, however. One only has to look at the categories of Pask, Saljö, Martin or Entwistle. Their categories are plausible, they help the educator to design and understand an educational situation, but they cannot be operationalized in the sense of an ITS. It is a simple case of metaphors for complex behavioural situations whose communicative and hermeneutic character would resist any reduction to if-when rules. Two problems result from the methodological status of a functional system with behavioural objectives:

Firstly, a concept of understanding [Stebler/Reusser et al (1994)] cannot be applied to intelligent tutorial systems, understanding cannot be the aim of IT systems. Secondly, true cognitive concepts do not exist as yet: »most of the work on learner modelling has been concentrated on the lower half of our framework, that is, on the behavior <–> behavioral knowledge mapping, with a relative neglect of the conceptual knowledge component« [Dillenbourg/Self (1992), 136]. The status cognition is assigned in IT systems becomes clear, if you look at the collected works of Resnick, Chabay, Larkin, Merrill, Ohlsson and others: Cognition is not used by them in the sense of cognitive psychology, but in the sense of »cognitive science«, the »nature of scientific thinking« [Larkin/Chabay (1989)], whose starting point is the observation that students approach scientific problems in different ways than experts, and whose aim it is to approximate the student's knowledge model to that of the expert. For Simon and Hayes (1976), on the other hand, understanding means something like solving the logic of a problem, e.g. understanding the operative structure of fractions. The approaches of the Pittsburgh school are also typical of how the term understanding (or rather comprehension) is used: for Greeno and Riley [Greeno/Riley (1987); Riley/Greeno (1988)], understanding means exclusively grasping concepts of natural science.

The reasons for the self-restriction to simpler cognitive concepts are attributed to the inadequate state of research: »The major problems facing ITS design at present stem from a lack of applicable models of human learning« [Tompsett (1992), 98]. The strategy of starting with the simple, in the hope that the theoretical foundations will be developed by and by, is only plausible, however, if one shares the belief in the unlimited progress of science. One might just as well argue that it will never be possible to model or grasp »understanding« with the means of tutorial systems or expert systems.

Systems and Examples

Name	**Reference**	**Subject**
SCHOLAR	Carbonell (1970)	Geography
MYCIN GUIDON	Shortliffe (1976) Clancey (1982) Clancey (1983)	diagnosis of infections in medicine
LMS/PIXIE	Sleeman (1987)	manipulation of algebraical expressions with error detection
SOPHIE	Brown/Burton et al (1974) Burton (1982)	error detection in electronic circuits, physics
PROUST	Johnson/Soloway (1987)	error detection in programming in Pascal
Geometry Tutor	Anderson/Boyle et al (1985a)	learning program for simple geometry
WEST	Burton/Brown (1979)	mathematics
BUGGY	Brown/Burton (1978) Brown/Burton et al (1982)	mathematics
Algebraland	Brown (1985)	mathematics
Quadratic Tutor	O'Shea (1982)	mathematics
STEAMER	Williams/Hollan et al (1983) Hollan/Hutchins et al (1987)	machine
OHM	Bonar/Logan (1986)	physics
DiBi	Spada/Opwis et al (1988) Spada/Stumpf et al (1989)	physics
SUOMO	Mandl/Bollwahn et al (1990)	physics
LISP Tutor	Anderson/Reiser (1985)	information science
BRIDGE Bridge Tutor	Bonar/Cunningham (1988a) Bonar/Cunningham (1988b)	information science
Smithtown	Shute/Glaser et al (1989) Shute/Glaser (1990)	economy
Physics Tutor	Jonassen (1992a)	hypertext system with integrated expert system on physics
GEO Tutor	Duchastel (1989) Duchastel (1992a) Duchastel (1992b)	geography
SEDAF SAMPLE	Micarelli/Balestra (1992)	computation of polynomials computation of electronic circuits

Name	Reference	Subject
BIOMEC	Giardina (1992)	biology/medicine
KAVIS	Fischer/Mandl (1988)	biology
ILIAD	Applied Informatics Inc., Salt Lake City, UT	medicine

I will briefly introduce some of the prototypes in the following, in order to establish a concrete foundation for the following analyses.[17]

WEST

WEST is based on an earlier drill & practice program that was realized with the authoring system PLATO. WEST was constructed on the model of the game »How the West was Won« by Burton and Brown (1982). It is a kind of board-game, like ludo, on the screen, with two players playing against each other. The moves determined by throwing dice consist of three figures which are to be combined through arithmetical operations. WEST is a combination of a »black-box« expert, who directs the moves and does not simulate human intelligence, and partial »glass-box« experts which are occupied with the analysis of sub-optimal player strategies. Burton and Brown describe WEST as a coach model that is supposed to realize guided discovery learning. The discovery component can only lie in the question of which combination of figures is employed as a move, i.e. in strategy. But the actual learning objective of WEST is arithmetic, in which there is nothing to be discovered. Thus the explorative component is reduced in my opinion to a drill & practice program dressed up as a game.

SOPHIE

SOPHIE [Brown/Burton et al (1974)] is an interactive model for electronic circuits. The students try out solutions to problems, can put questions to the system and will then receive answers, i.e. the tutorial component is unobtrusive until it is called up. There is no coaching yet in SOPHIE I. Brown and Burton have realized the same principles in BUGGY, a program for solving mathematical problems. Brown, Burton et al (1982) describe the history of the development from SOPHIE I to SOPHIE III, which led successively to a supplementation by a coach or instructor, an expert as problem-solver who can also explain his strategies, as well as by a natural language interface etc. What is interesting about SOPHIE in comparison to the other IT systems mentioned here is Brown's and Burton's different basic attitude, which wants to offer students a way to the active generation of strategies, and to a reflection and self-evaluation of their strategies. For this purpose, SOPHIE offers, among other things, a workbench as an element of a constructive learning environment in which the students can carry out miniature experiments, and a stimulating playful environment for strategic thinking.

Geometry Tutor

The Geometry Tutor [Anderson/Boyle et al (1985a)] focuses on proofs in geometry. The program compares the student's proof rules to its own, and supplies corresponding advice and hints, i.e. every student is finally judged by the ideal problem-solving process by way of mathematical proving methods which are stored in the program. The re-

17. Tabulated presentations of IT systems may be found in Fletcher (1984), Kearsley (1987), 22ff., and Clancey (1988b), 51. Overviews of ITSs and/or descriptions of prototypes may be found in Barr and Feigenbaum (1982), Sleeman and Brown (1982), Mandl and Lesgold (1988), Self (1988), Polson, Richardson et al (1988), Dillenbourg and Self (1992a), Ford (1987), Kearsley (1987). Wenger's (1987) book in particular offers a thorough and comprehensive introduction to expert systems and intelligent tutorial systems, their historical development, and their design.

presentation of the problem-solving space through directed graphs only corresponds to the abstract, formal solution, the proof, not to the geometry itself.

Anderson's technology is based on his own ACT* model [Anderson (1982)]. It is basically a model tracing approach, which compares the steps of the student's problem-solving with the expert solution. The Carnegie Mellon University LISP Tutor [Anderson/Reiser (1985)] and GIL, Graphical Instruction in LISP, a tutor for LISP with graphic programming support [Reiser (1992)], are chips off the same block.

PROUST

PROUST [Johnson/Soloway (1987)] is a tutor that detects non-syntactic errors and misunderstanding of programming structures (e.g. mixing up while and if) in Pascal programming, and decides how the error might be removed. PROUST reports to the student in which place in the program the error probably first came into being. The program is only a prototype and only has a good command of its area of responsibility with certain programming tasks.

BRIDGE

BRIDGE [Bonar/Cunningham (1988a)] follows a completely different strategy from PROUST [s.a. Bonar/Cunningham (1988b)]. BRIDGE is supposed to support the learning of programming in Pascal. It helps students to formulate their informal ideas into a structured programming plan, and after that to transform the programming plan into program structures. BRIDGE supports the programming plan's creation by way of a menu with options in simple English. The transformation of plan into program text happens with the help of another menu, from which the student can choose the Pascal expressions corresponding to the natural language expressions. The students can ask for help, but coaching only occurs if problems arise. The students can follow the problem-solving process.

STEAMER

Most IT systems are non-graphical. One exception is STEAMER [Hollan/Hutchins et al (1987)], a learning system on the topic of »power stations«, which simulates a graphically interactive depiction of the controls and console of a power station as interface. STEAMER is called an »interactive inspectable simulation« by its authors. The graphical components in STEAMER are not only operating elements which take the place of a keyboard, or mere illustrations of the language content, but an important explanatory part of the communication between system and user: the authors describe the graphical representations on the screen as »dynamic graphical explanations« (120) for that reason, which are well suited to depicting dynamic recursive models difficult to express with language means: »Such a qualitative graphical interface can operate as a continuous explanation of the behavior of the system being modeled by allowing a user to more directly apprehend the relationships that are typically described by experts«.

RBT

RBT (Recovery Boiler Tutor) is also a simulation of a machine [Woolf (1988)]. The interface consists of graphical representations of the machine and some menus. The program consists of four modules, the simulation model, the knowledge domain, the student model, and instruction strategies. Apart from conceptual and procedural knowledge, RBT also has implemented heuristic knowledge. A simple difference model compares expert and student, and reports the differences to the student. In this way the tutor guides the learning process without giving the solution to the student.

Smithtown

Smithtown [Shute/Glaser et al (1989) and Shute/Glaser (1990)] is a simulation for micro-economy simulating the laws of supply and demand. Additional tools allow for more open working methods, such as a notebook working like a spread-sheet, a tool for creating diagrams, and a menu supporting the formulation of hypotheses.

Quadratic Tutor

Quadratic Tutor [O'Shea (1982)] is an example of a self-revising tutorial system. It is an adaptive learning program on quadratic equations which is based on production rules, and which has a component continually modifying those production rules. *Quadratic Tutor* is based on an instruction model which has four aims: Increase the number of successful students per course, improve the average result in post-testing, reduce the individual average amount of time needed for a lesson, and reduce computer using time.

The tutor registers the relevant data and deduces a strategy appropriate to the respective situation. If no improvement in one of the four criterion areas occurs, the tutor can revise the decision and choose another strategy. »This work is particularly interesting because of its adaptive nature but has not been investigated to any great extent« [Kearsley (1987), 18]. O'Shea himself classes his tutor with discovery learning, but on the other hand describes the tutorial strategy as planned instruction method: »The teaching strategy centers on giving the student carefully chosen examples which increase the likelihood of a student discovering a particular rule« (311).

Algebraland

In *Algebraland* [Brown (1985)], the student's problem-solving process is depicted in a window in the form of a tree diagram. If the student ends up in a dead end, he can directly select the node from which he wants to try a new solution. The solution tree offers the student a second opportunity to reflect on the principles of problem-solving. This reflection is exactly what is desired, because – as Collins and Brown (1988) suppose – the abstract representation of the solution space in *Algebraland* fosters the formation of metacognitive strategies (7). The instructionalist's attitude towards the student is demonstrated very well in the discussion between Anderson and Brown: While Anderson thinks that the student should be kept on the correct solution path by the program as far as possible, because wrong solution strategies can only cause confusion and loss of motivation, Brown is of the opinion that students who are never allowed to choose a wrong track or undertake efforts of their own will never acquire metacognitive strategies [Collins/Brown (1988), 9].

IMPART

IMPART is a tutor for LISP that is supposed to realize guided discovery learning. Elsom-Cook (1988) outlines a »bounded user model« which is to allow a choice between different partial models of the learning process (172ff.). But the development of tutors with multiple strategies is made difficult through a lack of psychological theories which are not incomplete and can be formalized (174). For the prototype IMPART, a tutor for LISP, therefore the well formalized models of machine learning were used: »These models are currently quite simple, applicable only to special domains, and (generally) have no particular claim to relate to human learning« (175). Elsom-Cook calls the learning model realized in this way »extremely naive and simplistic« (177): »However, it does produce useful behaviour and is a major factor contributing to the smoothness of interactions with the system«.

MAIS

MAIS (Minnesota Adaptive Instructional System) [Tennyson/Christensen (1988); Tennyson (1993)] was created as an instruction model, but tried from the start to overcome the limitations of instructional design. MAIS is classed between computer aided instruction and tutor models by Wenger (1987), because it uses adaptive strategies. The system observes the student and decides how many exercises the student still has to do. The determination of this adaptive strategy is rather complex: The algorithm which calculates whether a student will solve a given rule is based on Bayessian statistics. Into the calculation go the number of already finished exercises, the criterion for mastering the subject matter, as well as the relative disadvantage which could arise from not letting the student go on in the subject matter.

DiBi

Spada, Stumpf et al (1989) have developed DiBi, a microworld for a physics problem, elastic pressure from traditional mechanics. The domain-specific knowledge consists of production rules, the user interface offers a graphical form of direct manipulation with several static and dynamic forms of feedback. They want to implement feedback by way of a natural language interface in addition. The learner's task is to formulate and test hypotheses inductively by experimenting. In order to support this process, DiBi shall have both passive and active adaptation.

SHERLOCK

The U.S. Army has been active in this area, too: a major part of the contributions in the reader by Burns, Parlett et al (1991) and in the reader by Farr and Psotka (1992) have grown out of the development of training programs for military maintenance staff, perhaps since one of the editors, Psotka, is himself a member of the U.S. Army Research Institute for the Behavioral and Social Sciences. The system SHERLOCK described by Lajoie and Lesgold (1992) was also developed for the training of technical military maintenance staff for the F-15 on behalf of the U.S. Air Force. SHERLOCK does not have a tutorial system in the traditional sense, but only supplies coaching if it is necessary or demanded. This method does not however provide sufficient reason in my opinion for classing this system with constructivism: »Our pedagogy parallels the cognitive apprenticeship approach in providing holistic instruction« (24).[18]

SHERLOCK II

The second development stage of SHERLOCK is a little more oriented towards constructivism. Lesgold, Katz et al (1992) want to open Sherlock II to »cognitive apprenticeship« and cooperative learning. The motivation for this modification is described by the authors, in obvious naivety, as follows: »Recently, Lesgold was asked to comment on the potential for training in medical education. In preparing his remarks for that setting, he was struck by the social character of medical education« (298). Sherlock II is supposed to enable problem-solving in a realistically simulated environment, an object-oriented model of a maintenance and repairs workshop. In order to open the program to collaborative problem-solving, the authors plan letting students work together in dyads or larger groups, and having them analyse and criticize each others problem-solving strategies. Explanation and self-observation become integral elements of the environment. They want to follow the concept of Collins, Brown et al (1989) in this, the triad of modelling, coaching and fading.

Lack of Success

McCalla (1992a) wonders why only few IT systems were successful, while all others remained largely unnoticed. He cites several reasons, among other things commercial failure and limited practical usefulness (110). The deciding factor in my opinion is that the prototypes are clearly bound to a particular knowledge domain. Any change of domain would require the effort of developing a special system. The developing effort seems off-putting for that reason. The developing effort is indeed very high: Lippert (1989) gives an estimate of 200-300 hours for one hour of instruction (13). »Because of the complexity, cost, and time to build these programs, most ITS have been designed and remain as prototypes« (12ff.). It is this very argument that Duchastel (1992c) has in mind when he asks why authoring systems in CBT have had more success than IT systems: »Despite this core architectural commonality,

18. Newman (1989), too, takes ideas from constructivism and plans to integrate cognitive apprenticeship methods in the ITS INCOFT, meant for training soldiers for an automatic rocket monitor. In the first stage this is realized by regarding human instructors as essential elements of the whole environment.

and despite the dream of eventually developing generic ITSs, the technology remains a hand-crafting one very unlike its older counterpart, computer-based training (CBT), from which it strongly distinguishes itself« (351). Woolf (1987), on the other hand, supposes the reason for most of the systems viewed as efficient having remained in the developing stage in the theoretical problems of ITS, not in programming difficulties or the time involved (229) [cf. Woolf (1988), 4].

Clancey (1989) has made the experience that his programs are not being used. This experience has made him realize that something must obviously have gone fundamentally wrong right from the design process. His hypothesis is that the social model of action to which he as all other AI researchers adhered consisted of checking and publishing theories, but not of dealing with questions of practical implementation: »The effect is that our technological goals–exploring the space of what computers can do for instruction–dominated over our educational goals« (10). He then demands in agreement with the constructivist paradigm of »situated cognition« that the very design process of learning software must be socially embedded: »researchers must participate in the community they wish to influence« (9).

Expert Systems and ITS

As could be seen from the descriptions of the various prototypes, there are a number of transitions between authoring systems and ITS, ITS and constructivist learning situations, and ITS and simulations:

- Elsom-Cook and O'Malley (1990) try to establish a bridge between CAL and Intelligent Tutoring Systems with ECAL. ECAL (extended computer-assisted learning) was developed especially for integrating ideas of artificial intelligence into a traditional CAL environment.
- With BIOMEC, Giardina (1992) describes a coach that is supposed to allow discovery learning and apprenticeship. The coach is a dynamic component which establishes relations between the expert knowledge in a particular field and the knowledge of the student.
- Jonassen and Wang (1994) try to establish a combination of an ITS with an expert system and a hypertext with *Physics Tutor*. *Physics Tutor* is a prototype ITS which is meant to explore the practicability and generalizability of the ITS concept.

An expert system is an »intelligent« program which has a certain knowledge and can make decisions with the help of inference rules and procedures, and which is thus able to solve problems or formulate hypotheses for problem-solving [Woodhead (1991), 35ff.]. Expert systems consist of a knowledge base (with facts, rules and strategies), and an inference machine. The rule knowledge which an expert system needs can be divided into propositional, analogous, and procedural knowledge. Occasionally, one format can be transported into another, but this is not always the case. Therefore most expert systems can make do with one type of knowledge. The objective of expert systems is to collect the knowledge of experts in the knowledge base in order to use it to solve concrete cases like diagnosing a machine (car, aeroplane, computer), a patient, a law case. In teaching, expert systems are therefore most easily combined with methods of case analysis, the so-called »case based teaching«.

Most expert systems are logical systems that transform a knowledge base into hierarchically structured if-then rules. The experts are partly not conscious of these rules, they act without being able to express their own experience in the form of rules, or rather »experts do not need to have formalized representations« [Winograd/Flores (1987)]. The experts' performance is therefore analysed beforehand with sophisticated methods, although »it is fruitless to search for a full formalization of the pre-understanding that underlies all thought and action« (99). Because the analysis of expert knowledge is difficult, Winograd's and Flores' objection that transmitting experience to the knowledge base must remain an unreachable aim (98) applies. Expert systems differ in that they either follow the tree structure of rules backwards from a given aim (backward chaining), or apply them to problems from given conditions (forward chaining or inferencing). Through asking the user for further information, expert systems get the required knowledge in order to decide which premises apply, and at what point which rules can be used.

Expert systems are used as »Tools, Tutors and Tutees« [Lippert (1989)]. Intelligent tutorial systems can attach an interpreter and an explanatory component to the knowledge base which are organized in the form of an expert system; they could also organize the tutorial decision about didactic strategies in the form of an expert system. Expert systems which were constructed with tutorial intent are e.g. ZEERA [Marcoulides (1988)] and STAT-EXPERT [Karake (1990)], both are types of programs meant to support students in understanding static analyses, and the expert system for foreign language learning by Nyns (1990).

Two features seriously distinguish expert systems from IT systems [Clancey (1987)]:

- In contrast to the knowledge model of tutorial systems, expert systems do not strive to simulate human reasoning or problem-solving.
- In contrast to IT systems, one cannot learn anything from expert systems, since expert systems merely acquire the necessary data by asking the users for information, and then draw their conclusions from them independently and 'invisibly'.

For that reason, Clancey had to restructure the expert system MYCIN for diagnosing infections [Shortliffe (1976)] when he wanted to develop the tutorial component GUIDON [Clancey (1987)]: »There are two important kinds of explanations that MYCIN cannot give: it cannot explain why a particular rule is correct, and it cannot explain the strategy behind the design of its goal structure […] At a certain level, MYCIN is aphasic – able to perform, but unable to talk about what it knows« (198).

Adaptivity – Adapting to the Learner

One of the most important aims of IT [Intelligent Tutoring] systems is the individualization of the learning process. An ITS tries to achieve this individualization through the system's adaptivity. As a prerequisite for an appropriate employment of adaptive tutorial strategies, a student model with diagnostic functions must be set up which is able to determine the learner's current level and history, and to transmit this information to the tutor.

The basic question is whether man should adapt to the computer (this was general user philosophy in the age of command systems, before the invention of windows systems), or the computer should adapt to the thinking processes of its user. "Tutorial programs are called 'intelligent' if they are able to conduct a flexible and adaptive dialogue with the learner" [Mandl/Hron (1990), 19]. This is the way sought by artificial intelligence research, the difficulty being that the computer is supposed to adapt to something which has not yet been (and perhaps never will be) fully researched by science: "But, in our view, an unsurmountable problem arises on this way. At the present state of knowledge we are unable to implement anything except processes which are the object of formal logics" [Bastien (1992), 183]. Bastien sees a possible compromise in concentrating on intelligent interfaces. This would presuppose a mental or cognitive model of user thought processes as well, but it could be a restricted one based on a simple cognitive theory.

Duchastel's (1992a) argument for preferring tutorial systems is his rejection of open hypermedia systems for didactic purposes: "Hypermedia is a non-pedagogical technology, one which is open to learning through browsing, but which must count on the student's own intelligence for learning guidance. Didactics, on the other hand, and all technology that supports didactics, are essentially goal-directed processes that aim to achieve a result that is focused" (69ff). Interesting here is Duchastel's view that hypermedia is a "non-pedagogical technology" because it allows browsing, while he defines didactics and didactic learning environments as "essentially goal-directed processes" (201). For Duchastel, didactics starts with the definition of learning goals and ends with adaptive tutorial rules representing pedagogic knowledge. He must therefore view the freedom of hypermedia systems as a weakness, because they are not able to adapt cognitively to the learner. The instructional strategy arising from the tutorial influence of the ITS with its pedagogical knowledge on the learner is called "tasking the student" by Duchastel (probably a more modern variant of the earlier "prompting"?). The compromise between "tasking" and browsing which becomes necessary when adding multimedia to the tutor is then described by him as "provok[ing] the student into browsing"! Duchastel equates didactics with instruction. Why should an instrument which allows and facilitates learning (and Hypertext is often described in this way) be a non-pedagogical tool? Is a teacher who encourages independent problem-solving in his students no didactician? I would claim that he is a better pedagogue than the teacher merely giving expository instruction. Man anyway undergoes his most important learning processes before being exposed to the formal, institutionally induced learning in school education.

Why should didactics be something else ("on the other hand") than learning? Didactics is a method which provides help for arranging learning processes and learning environments, and support for decisions about learning situations and learning aids. This includes the planning of open, exploratory, even constructivist, and other learning situations. Do exploratory situations not contain any goal-oriented processes? Why should I accept the restriction that didactics only describes or prescribes goal-oriented processes of the tutor or instructor? I cannot help thinking that Duchastel equates didactics with instruction and confuses learning with instruction.

Planned Adaptivity

Duchastel's argument serves to justify adaptive systems: "In contrast, HMSs [i.e. hypermedia systems, R.S.] do not adapt cognitively to the student; this is their weak point". I can only understand this sentence if I assume that Duchastel thinks that adaptivity is nothing but the program's adaptation to pre-imagined types of learners invested into the program design by the designer. The next sentence seems to support the correctness of this interpretation: "Adaptation is the essence of what is known as pedagogical knowledge (the tutorial rules of an ITS), which in turn can be characterized mainly as curricular knowledge". The tutor and its adaptivity are defined by the curriculum, the catalogue of learning goals, and the designer. I cannot, however, call this an adaptation to the individual. On the contrary, this process must lead to the adaptation of the individual to the pedagogical syllabus.

Adaptation could also refer to a learner examining a subject with a wide range which can be processed individually and interpretatively as well as selectively. The learner furnishes the interpretative performance and the "subject gives way". It can do so because it is rich, varied, and allows interpretation. This form of hermeneutic adaptivity I would consider more demanding and individual than the instructional adaptation to ideal types of learners. This form of adaptivity is unthinkable, undidactic, for the instructional design and tutorial systems. The pedagogics of ITS cannot do other than plan adaptivity.

The adaptive function must lead to a continually widening differentiation of learner parameters, because adaptation would otherwise remain clumsy and artificial, while adaptivity wants to achieve a form of "naturalness". But a number of problems arise from this (quite apart from the fact that pedagogical psychology and cognitive science have not as yet identified all learner parameters):

- There is a danger of a potential combinatorial explosion of search and diagnosis strategies in the tutorial space.
- Logical and other consistency of all the parameters becomes problematic with high numbers of parameters.
- Internal consistency is doubtful, because the numerous learner variables are rather heuristic categories and in many cases overlapping, e.g. intrinsic, intentional, active, self-regulating etc.

Microadaption

In the end, the adaptation practised by IT systems is a form of microadaptation. Adaptation to student models is to be achieved through the employment of different strategies in the instructional system. VanLehn (1991), for example, distinguishes "explanation-based learning" from "similarity-based learning". *Sierra*, an arithmetic learning program, uses a mixture of both strategies. The first strategy assumes complete mastery of the domain and presupposes that stored knowledge can be accessed and applied to other cases. The second strategy compares examples, registers similarities and differences, and formulates generalizations. What was initially intended as a psychological model of learning (19) turns out to be an inadequate reproduction of actual processes of learning (21). The intelligent tutor can supplement an explanation with an example, it can change the level of explanation etc., but it cannot react to individual problems which cannot be recognized by the diagnostic component, let alone problems outside the cognitive domain, e.g. concentration, motivation etc. Most error-detecting systems are not able to vary their strategies in the way that would be necessary: "When learning failures occur in either approach, the system can only reteach the same material in the same way that was ineffective the first time" [Snow/Swanson (1992), 604].

Adaptivity and Control

ITS developers aim at the individualization of the system through adaptivity, but is the result not rather control over the learner? There are studies that prove (allegedly) that learner control over the program does not produce better learning results, that adaptive programs achieve better results. Such statements can only be accepted with the precise caution and restrictions which have been outlined in the chapters on learner control and evaluation, since these results depend on preconditions, strategies, and styles of learning, on the type of application and its context. Knowledge of learning processes and tutorial strategies contains more than a little "common sense knowledge": It is not a sensible strategy to heighten granularity (to refine the steps of the learning process), because the system will become even more tight (more controlled). The more detailed the diagnosis, the farther the system departs from actual psychological learning processes. Instead, there are even proposals to allow inexact diagnoses, imprecise, fuzzy diagnoses.

Adaptivity through teaching methods

What exactly can we understand by adaptivity? What does an adaptive system look like in practice? Tutorial systems cannot stand up to a comparison with teachers: "Admittedly, adaptability in the best systems is rather coarse when compared to the way human teachers can weave diagnosis and didactics tightly together. The ability of teachers to move back and forth between compiled and articulate knowledge, in both diagnosis and didactics, also contrasts strikingly with current systems in which diagnosis in terms of compiled knowledge is the norm" [Wenger (1987), 426]. Which variants exist for the tutorial component? The strategies vary from corrections, via explanations up to the presentation of examples and exercises. Adaptive systems would have to command a multitude of teaching methods and be able to analyse a multitude of learner variables in order really to fulfil their aim: drill & practice, tutorials with exercises, interactive construction, Socratic dialogues, exploratory learning environments, etc. We can observe a lively experimenting with prototypes in just this respect. A diagnostic system which presents counterexamples in order to help modify incorrect learner hypotheses is presented by Plötzner and Spada (1992). Diagnostic modules which are supposed to cope with uncertain hypotheses are described by Eshelman (1990). But there are fundamental limits to the modification of didactic strategies resulting from the restriction to the domain and observable learner behaviour: the tutor cannot engage in metacommunication. That is why I cannot agree to Wenger's claim (1987) which assumes that these shortcomings can be removed by implementation into a communication environment: »Bringing more intelligence into knowledge communication requires an understanding of the communication environment in which it takes place […] Hence, computational models of knowledge communication will require new theories of knowledge communication as computer-based systems evolve and as research in artificial intelligence and related disciplines provides more powerful models« (426).

Limitations and Hopes

What are the latest developments in tutorial systems? "overhyping and overpromising", as Reigeluth (1992) claims (52): many reports and presentations on ITS remind me of 'show and tell'". Or do we just a lack 'a little theory', as Goodyear (1992) supposes?

The field of intelligent tutorial systems seems to have become stuck in the programmatic phase: even if one looks at the articles of just one journal on the topic of ITS, the same statements, systematizations, and fall-backs on AI literature are endlessly repeated. I have seldom encountered so much redundancy in one place before, and seldom seen such a small community of scientists repeatedly publishing the same and at the same level of development (Anderson, Brown, Duchastel, Jonassen, Lesgold, O'Shea, Self, Sleeman). Even if a program was "tested on thousands of pupils", one can assume that the program was not, as Clancey puts it, "in practical use", but merely tested on pupils as "experimental subjects" in widely scattered test series, e.g. DEBUGGY [Burton (1982)]. There is a host of articles in the field of ITS which carry "prospects", "perspectives", "future" or similar terms in their titles. After looking through the literature on ITS, I cannot help this spontaneous shout of irritation: "I am sick to death of LISP, Prolog or Pascal learning (ILE / PROUST / CMU Lisp Tutor / Bridge Tutor / GIL / TAP) in intelligent environments!" An overview of IT systems concerned with programming can be found in van Merriënboer and Krammer (1992). There are special issues of Instructional Science on this subject (20, 2/3), (19, 4/5).

Research in the field of tutorial systems deals mostly with the problems of problem-solving strategies independent of the domain. The hope behind this, of finding general structures which could be employed in any tutorial shell, rests on the hypothesis that the cognitive concepts can be detached from their respective practice as abstractions and stored in that form, a hypothesis that has been challenged from the constructivist point of view [Clancey (1992); cf. Ridgway (1988)]. Such a goal has not even remotely been achieved up to now. On the contrary, the highest number of systems exist in physics and in the field of programming languages, both fields of knowledge which show high stability and whose concepts can be reformulated as algorithms. These are the exact criteria given by Jonassen (1992a) as the reason for his choice of domain for his tutor: "Physics was chosen as a subject matter domain because it possesses a highly stable and well-defined semantic structure" (195). Mandl and Hron (1990) point out this restriction of the field of knowledge as well: "Present Intelligent Tutoring Systems consider mostly elementary and algorithmic subjects, while semantically rich fields have been neglected" (27). Their conclusion is: "One must, however, state critically that learning with ITSs concentrates on facts and subjects which lend themselves to logical analysis and are highly regulated. The computer is mostly used to impart logically functional knowledge which characterizes technology and science. Social knowledge has not been considered. The same applies to the arts and aesthetics, as well as to physical and kinaesthetic experience. ITS cannot simulate true-to-life experience." (28ff) [s. also Dreyfus (1985); Hammond (1989), 171].

Primitiveness of the Student Model

The limitation of the domain is one of the critical points in IT systems. Another critical point is the present primitiveness of the student model, which covers much too few learner characteristics. In this respect, IT systems build on the development of cognitive theories of learning. Hoping for progress in intelligent tutors presupposes that there are theories capable of describing the desired intelligent processes. This is the point at which psychological criticism comes in. Landauer (1991), for example, in a discussion of design decisions for user interfaces, points out that there is an influence of theory on practice, but that this does not consist in providing precise, clearly outlined practical instructions: My contention is simply that the theory of human cognition is now and may forever be too weak to be the main engine driving HCI" (60ff). A third critical point is the current state of tutorial strategies, which are designed in a too linear and sequential manner and offer too few choices: "Tutoring systems certainly cannot make better choices and decisions than teachers in all facets of teaching activity. But in some, they can be more complete and more reliable". But Vergnaud (1992) has hopes that the limitations of the pedagogic function of IT systems can be surmounted: "They will probably not be able to interpret students' behavior before a considerable amount of research has been conducted" (307).

That is Goodyear's (1992) opinion as well, who bewails the limitations of current tutoring systems, but on the question of the possibility of integrating pedagogic knowledge into IT systems states hopefully: »If our goal is to encode pedagogical knowledge in an ITS to support simulation-based learning, for example, the knowledge representation formalisms of contemporary AI are terribly restrictive. But that is not an argument for abandoning the enterprise. Rather we need to recognise the utility of early explorations in pedagogic knowledge engineering, through which greater and more specific demands can be made on the tools and techniques of cognitive modelling« (397ff.). The tutor model, understandably enough, is the part of the IT system for which the instructionalists have offered their expertise to the ITS designers, but apparently in vain, because Reigeluth (1992) criticizes the ITS developers' inability "to recognize the importnace of the soft technology – instructional theory – for guidance as to what the instruction should be like" (52). Jones' (1992) criticism of the state of instructional design maybe seen as a reply to such criticism: "instructional designers have not yet specified their theories at a sufficient level of detail for use within an ITS" (5).

Reductionism I: Knowledge Base in ITS

Intelligent tutoring systems differentiate between declarative and procedural knowledge. Procedural knowledge means rule knowledge relating to areas of instrumental rationality, while declarative knowledge denotes knowledge about objects, features and events, i.e. factual knowledge. Procedural knowledge is often called prescriptive, while declarative knowledge is often called descriptive.

Restriction to nomological knowledge

Ohlsson (1992) lists the types of abstract knowledge which form the basis of ITS domains: natural science, artificial, mathematical, logical, moral and conventional knowledge. By artificial knowledge, Ohlsson even understands knowledge of social institutions, concerning moral knowledge, he makes a restriction to something like "moral prescriptions"(84). From the absence of other types of knowledge, it is evident which types provide unsurmountable difficulties for ITSs: methodological, historical, social, psychological, aesthetic, anthropological and ethnographic knowledge. All knowledge types used as foundation by ITSs are nomological types of knowledge "which lend themselves to logical analysis and are strictly rule-bound" [Mandl/Hron (1990), 28], while hermeneutic areas of knowledge are avoided – apparently, ITS designers are not aware of the existence of non-nomological knowledge –, since in the few excursions to the field of arts or social science, Ohlsson makes a reduction, dangerous for the pedagogical context, of social science topics to analytical, instrumental rationality dimensions: In the list of examples with which Ohlsson illustrates his knowledge classification, we find the following examples, among others: That the "law of supply and demand" appears in social science may just about pass, even though economic science itself is not very clear about the law character of this pair of terms; but the absurd reduction of the dialectics of historic materialism to if-then statements is not acceptable: »The principle of historical materialism which says, roughly, that when new tools for the manufacturing of economic goods appear, there will be a political revolution which transfers political power from the owners of the old tools to the owners of the new tools, followed by a restructuring of political and social institutions to fit the new manufacturing tools« (76). Quite apart from the fact that hardly any proponent of historical materialism from Feuerbach to Marx would recognize himself in this law-like formulation, this attempt of a nomological reduction of theory completely misjudges the dialectical base and complex social and historical categories of materialism. Even in the area already restricted by the term "moral conduct" we find examples which simply do not seem to belong here, e.g. "The Golden Rule which says that you should behave towards others as you want them to behave towards you" (77). To overlook the complex forms of relational thinking and pass off such everyday "proverbial wisdom" as knowledge means a lot of cheek, indeed.

Ohlsson assumes the following reason for the justification of his knowledge classification: "Cognitive science has as yet neither verified, improved, nor produced a grounded rejection of this classification of knowledge" (84). From where does he take the substance of this statement? That simply is not true! Cognitive science and methodology are much older than Ohlsson's attempt, have always viewed this problem in a completely different way, and thus have no reason to enter into a discussion of this voluntarist classification. Ohlsson's examples may be crude and are perhaps not shared by all ITS designers, but they are only extreme forms of a consequence which is immanent in the ITS concept. The compulsion to restrict knowledge is methodologically inherent in the chosen approach, and not coincidental to individual representatives of this school of thought.

The Jam-Jar Problem

I take the trouble of quoting one of the most superfluous pages in scientific literature in order to show the imaginary problems one occasionally encounters in the analysis and definition of the knowledge component: I call it the "jam-jar problem". Ohlsson uses it to illustrate, in two full pages of his article, the difference between procedural, declarative, and abstract knowledge. The example is: 'How do I open a jam-jar whose top is stuck?' Ohlsson rehearses in detail what form the solution would take as declarative, procedural, and abstract knowledge. He solves the problem in this way: "The most elegant solution to this problem is to heat up the jar by putting it in hot water". Granting logic and the validity of natural laws: what is supposed to be 'elegant' about this solution? After this procedure, *am I supposed to spread hot jam on top of my cool bread and butter?* In order to solve such a practical problem, man has always used purely empirical knowledge:

1. Tap against the side of the jar top with a solid instrument.
2. Turn the jar on its head and slap it with your fist.
3. Take a pair of tongs with a round opening (available in any household goods store) and twist off the top.

The natural laws enlisted by empirical knowledge (letting air into the vacuum, inner pressure vs. outer pressure, application of leverage) are not reflected by the everyday problem-solver. It is, in fact, not a case of declarative knowledge, but simply handed-down empirical knowledge. To impart this knowledge through an ITS would be beyond any cost-benefit-relation and totally inappropriate. To Ohlsson, however, the example is an "insight problem" whose solution is arrived at in an "extended impasse"!

I have argued previously that the structure of an ITS necessitates a concentration on nomological knowledge. Kearsley (1987) supposes a different reason for the obvious restriction of the domain, i.e. the developers' intention of developing prototypes for testing purposes: "their initial goal was to explore the capability of AI technology in the instructional process than to develop usable instructional systems" (28). The domain models seldom contain heuristic principles. Often, they are simple quantitative simulation programs [Hartog (1989)]: "The domains of these systems are highly artificial. Popular domains for intelligent tutoring systems are: mechanics, electronics, mathematics, computer languages, games, medical diagnosis" (197). It is only in the field of causal conclusions that ITS and learner can be made to coincide (198), although there is no scientific model of causal argument and although this form of argument is considered non-scientific in wide areas.

One of the few examples that seems to go beyond this restriction to knowledge of the natural science kind is Costa's (1992) system MORE, which allegedly copes with incomplete statements and logical contradictions: "We have chosen a non-procedural domain to test the principles and ideas underlying our system, the domain of French XVII century history" (101). But it becomes clear that the other kind of knowledge MORE deals with is characterized as a move to problem areas of incomplete and contradictory statements, an attitude that is still oriented towards the ideal of logical inference.

One wants to get to rules faster, and thus develops an entire branch of research dealing with the automatic extraction and generation of expert systems and knowledge bases. Again, we encounter methodological problems. Some developers work with verbal protocols and information supplied by the test subjects themselves. But that kind of information is often not based on introspection but merely reproduces superficially acquired, a priori knowledge, commonplace theories etc. And there is already a new research branch dealing with nothing but the verbal protocolling method and knowledge representations of the researched experts, their search strategies and decision processes. Since these are, as a rule, independent of the domain, there would be plenty of research to do in the future. Reports like those of d'Ydewalle (1992) and Engel, Bouwhuis et al (1992) suggest that this may also lead to a reductio ad infinitum, a splitting up of research into atomic problems, the consequence being that individual results can no longer be compared or reduced to a common denominator.

Reductionism II: the Learner Model in ITS

Let us start with a quotation of one of the foremost representatives of student models: »The 'learner model mystery' is this: Why is it that every conference and workshop concerned with 'AI and Education' has sessions on 'learner modelling' and yet the papers within those sessions have little discernible connection?« [Self (1992), 17]. Self is optimistic all the same, and tries to point out the common features of the obviously different approaches in the reader by Engel, Bouwhuis et al (1992) by integrating them into a general framework. He succeeds in doing this, although the studious reinterpretation of the approaches shows clearly that all the three approaches under review deal with different questions within that framework. One could easily find hundreds of such articles which treat the same problems in different ways. Another reductio ad infinitum.

Current state of research

I agree with Self's assessment of the state of research: »research on learner modelling covers a diverse spectrum of techniques, approaches and philosophies. Progress in the field, and in intelligent learning environments generally, is impeded by the difficulty individual researchers find in comparing and analysing the methods developed by others« (25). I do not, however, share his optimistic attitude that such differences may be overcome by a merely formal framework. These are differences in quasi-theories, and in view of the methodological weaknesses of such theories, there can be no common ground. Mandl and Hron (1990) seem to agree with this statement: "In cognitive science, especially cognitive psychology, Wissenspsychologie [knowledge psychology] and artificial intelligence research, there are mere rudiments of secure findings on knowledge acquisition which might provide the basis for ITS development." (27). Pereira, Oliveira et al (1992) point out that even a cooperation of scientists in all relevant disciplines would not be of any help, “simply because there are no available models either in psychology or education that would apply readily to the ITS situation” (209). Self’s optimism is influenced by the positivist piecemeal technology, the idea that one could succeed in dividing up the big research question into little pieces, successfully research these, and in the end add up the pieces again into one cake. The trouble is that the pieces have changed shape in the process.

Individualization and Learner Control

For McCalla (1992a), the need for student models is justified by the goal of individualization and the learner control necessary for this. He does not believe that these goals can be achieved without a student model: »The need for student modelling arises primarily as a by-product of the need for individualization and student control. Without detailed knowledge of what students actually do, it is impossible to allow the student any control and it is impossible to modify the system’s behaviour to correspond to specific, individual needs of the students« (112). McCalla’s position shows the interlacing of instructionist thinking with the IT systems: only when the program (the tutor) can assess correctly how conscientiously the learner will follow the instructions, may control be entrusted to him. There is a very limited idea of autonomy and independence in learning behind the concept of adaptivity in IT systems.

The term student model can assume various meanings: the model may consist of just a list of features, or it may be a set of coordinated parameters, a model in the sense of a simulation. The latter, in view of the variety of parameters and the poorness of scientific research in the field, is probably impossible, or possible only in a very restricted domain. Often, the student model consists of nothing but the knowledge structure of the domain, which is translated into domain-specific rules in the form of hypotheses and predictions [Plötzner/Spada (1992), 113]. A special subset of these rules forms the individual learner’s knowledge structure. In most cases, this very subset is completely underdeveloped [Kearsley (1987)]: »existing ICAI systems have ignored many potentially important student variables in the diagnostic and prescriptive process by relying solely on the student’s response (or response pattern) to a given question« (35).

A differentiation of the diagnostic component by styles of learning is striven for, just like a dynamic recurrent transformation of tutorial strategies in the course of the program, but realization remains rudimentary up to now and will never reach the complexity which has been proved to be necessary by the research of Entwistle and Saljö and Marton, if only because these and other psychological-analytic theories of the learning process and its interacting variables are not available: »However, a satisfactory integration of the system’s diagnostic process with the learner’s learning process has yet to be achieved. It demands a more valid psychological model of learning (as well as domain representation) than we are currently able to provide« [Dillenbourg/Self (1992), 130]. The practical possibilities of variation are rather disappointing: “Almost all the systems I have reviewed enforce one standardized style of learning, described as hierarchical, structured, sequential, top down, and goal oriented" [Rosenberg (1990), 186]. Tompsett (1992) doubts whether the gap between pretension and reality can ever be overcome: »Some advances have been made in terms of learner styles, but styles exist only as a set of discrete entities rather than a multi-dimensional set of characteristics. Knowledge of how to match learner characteristics and resource generation without producing two set of resources appears to be a unrealisable in the future« (98).

Student models, as a rule, are domain-specific. But the assumption that scientific progress will make it possible to arrive at a universal student model is inherent in ITS approaches. One of few examples of a model intended as a general student model is "G" by Meurrens (1992). To this end, IT systems need better cognitive theories of learning, although Rosenberg (1990) doubts whether developers take advantage of theories of learning at all: "Overall, there is little evidence that the views of learning embodied in ITSs are based on anything but their implementors' intuitions" (186). Oliveira (1992) is sceptical about the assumption of a universal student model: »there currently does not exist, and probably never will exist a 'universal model' able to represent the process implied in a learning situation, however well-defined [...] What does exist are general theories about learning, which although fundamental to the framework guiding this study, are not sufficiantly open to formalization to permit the construction of an operational model in the sense we intend; that is, a model capable of modelling learning in a situation of assisted teaching, clarifying the mediatic foundations of interaction between man an computer« (8). But even if it were possible to develop the tutor on the basis of a universal user, there would be insoluble problems, because a general tutor must needs pass over individual learner characteristics: »The evolution of intelligent tutorial systems is currently facing an important dilemma: either it is to base itself on pupil models which are sufficiently simple and precise, yet, as they are only relevant to specific learning situations, are only locally operational; or, if we hope to use them in more general situations, the models either cease to be precise enough to be operational or they quickly become too complex and the systems lose a great deal of their efficiency«.

Basically, research must go into ever more detail in order to meet the requirements of an ITS: analogies, explanations, and transfer must be examined, the effectiveness of the kind of examples introduced into the learning process has to be studied in detail, e.g. whether it is sufficient to give one or two examples, etc. Next, one would have to research how the relevant factors can be combined and in what way they depend on context. Such a study of questions of detail is the one by Pirolli (1992), who researches the acquisition of programming ability in recursive functions and in this context examines the role of examples and self-explanations. If these requirements are taken seriously, research will enter into the atomized areas of learning, an endless task that will lead to a complete fragmentation of research, and, eventually, of learning processes as well.

The idea of adaptivity in tutorial systems leads one of their supporters [Lippert (1989)] to state: "CAI is teacher-centered, while ICAI is student-centered" (11). That is a rather rash conclusion. ICAI is constructed by the designer for the ideal learner. On the contrary, tutorial help may even lead to a reduction of the learners' own activity once the learner begins to rely on them, which in turn may "strongly impede the transfer of acquired knowledge to new problems or under different conditions" [Spada/Opwis (1985), 20].

»What is problematic from a psychological and pedagogical point of view is that tutorial systems often give little room to the learners' own activities. The empirical findings on the effectiveness of free choice of learning strategy are admittedly controversial, due to the difference of the teaching/learning paradigms under review, but it is undisputed that knowledge acquisition and knowledge modification are constructive processes which demand that the learner take an active role« [Spada/Opwis (1985), 19]. Against the background of a comparison of John Dewey's and Herbert Simon's theories, Bredo (1989) characterizes the pedagogic model inherent in IT systems and reaches conclusions which seem to contradict one of the basic presumptions of ITS designers, who apparently always assume that tutorial advice is a form of learner involvement: »It embodies a passive view of the learner that, unlike Dewey's, cuts them out of fuller interaction with their physical and social environments, making it more congruent with the presumptively docile and isolated subject of a psychology experiment than with learners observed under naturalistic conditions« (28).

There are several conclusions one can make about the use of IT systems in practice from the state of the tutorial component. Spada and Opwis (1985) think it sufficient to formulate clear restrictive rules for the employment of such systems: "Intelligent tutorial systems should in any case only be considered for part of the instruction time, because the dialogue with the computerized artificially intelligent system differs from natural social interaction in important features. And there is of course the problem of the extent of learner supervision." [Spada/Opwis (1985), 20]. Megarry (1988) thinks it would be more sensible to do entirely without learner models: »the rôle of the computer should be organizing and representing knowledge to give the user easy access and control, rather than trying to create a model of the learner and seeking to prescribe her route through it« (172). Despite all efforts to achieve adaptivity, the result in his view rather resembles control: "To treat the learner as a dumb patient and the computer system as an omniscient doctor is both perverse and arrogant" (173). Chiou arrives at a similar view (1992): »we believe that learning strategy had better not be embedded in the computer-based learning environment [...] We believe that intelligent learning behavior had better be done by the learner, not by the computer« (7).

Twidale (1993) reports that users do not go along with their minds constantly being made up for them, but react by "swimming against the current", so to speak. He notices that learners working with the IT system EPIC, an intelligent learning environment for proof construction in propositional logic, make mistakes on purpose (164) in order to get at the tutorial reaction. A summative evaluation might lead to misinterpretation of these data. Following this discovery, Riehm and Wingert (1995) find more general weaknesses in IT systems: "such behaviour makes clear that an ITS restricted to continuous correction of mistakes, 'artificial intelligence' notwithstanding, is nothing but a training program that cannot go beyond learning by 'trial and error'" (159ff).

In view of domain-specific applications, a desire for supersystems is expressed: in BACEIS (Behaviour, Attitudes, Cognition, and the Environment as Interacting Systems), Hartman and Sternberg (1993) describe a model of the factors influencing intellectual performance. BACEIS is to include internal and external factors describing development, storing and transfer of thinking and learning abilities. The internal supersystem consists of cognitive and affective subsystems interacting with both each other and the external supersystem and its components. The external supersystem contains academic and non-academic subsystems [no comment!].

Reductionism III: Interaction in ITS

Interaction in IT systems on the one hand serves to advise learners, and on the other to gain sufficient data for an analysis of the learner on which to base its tutorial strategy. By way of answer to the learner's actions, the system can automatically generate displays as well as arrange exercises and examples. The ability to generate new instructional displays is, however, limited by the existing set of learning units contained in the knowledge base [Kearsley (1987), 35]. There is a differentiation between systems which are oriented towards guided learning and those rather trying to realize exploratory learning with the help of the microworld concept [e.g. Mandl/Hron (1990), 22]. Tutorial support is especially difficult in the latter, since the emphasis there is rather on: formation and testing of hypotheses, conducting of experiments and evaluation of the results. That is why one should rather choose simulation in this area.

The quality of interaction, and thus learning, in an ITS is directly dependent on the representation and modelling of both the contents and the strategies by which the contents are to be presented, and this is not on of the "'intelligent' features of an environment" [Giardina (1992), 56]. The overwhelming majority of systems, however, shows clearly that interaction in ITSs is a highly restricted, artificial form of interaction and communication in spite of the quasi-natural language interface. Just compare the example reported by Romiszowski and Chang (1992) about the interaction process in an experiment in which students communicated over a network with the help of hypertext tools for the duration of one semester.

The method dominated by program control and top-down approach contains a basic pedagogical attitude demonstrated clearly by Anderson, Boyle et al (1984) when they argue that the tutor should keep its learner on the optimal path so that he does not flounder, because this would lead to confusion, waste of time and loss of motivation. Collins and Brown (1988) consciously set off their strategy in Algebraland from this view: »In contrast we argue that unless students flounder they will never have the opportunity to learn the kinds of metacognitive strategies suggested previously. We need to create environments where students can flounder and where the system helps students profit from this floundering by making it explicit« (9). This is yet another contribution to the discussion of the reasons which have led many developers to an aversion against learner control.

Example from the LISP Tutor [Anderson (1993), 148ff.]

Task

Define a function calles „create-list“ that accepts one argument, which must be a positive integer. This function returns a list of all the integers between 1 and the value of the argument in ascending order. For example
(create-list 8) returns (1 2 3 4 5 6 7 8).
You should count down in this function, so that you can just insert each new number into the front of the result variable.

Process

1.(defun create-list (num)
(loop)
You will need local variables in this function. So before you code anything else, there is a particular LISP operator you need to code.

2.(defun create-list (num)
(let (( )
<BODY>))
Which of the following do you want to do?
PRESS: IF YOU WANT TO

1 Initialize a variable to hold the list of digits between 1 and the value of the parameter.
2 Initialize a counter variable to keep track of how many times we go around the loop.
3 Have the tutor chose.

Menu choice: 2

3. (defun create-list (num)
(let ((count 1)
<OTHER INITIALIZATIONS>)

```
        <BODY>))
```

In this problem we won´t want to start counting at the same value each time we call the function, so we can´t initialize the counter to a constant like 1. How is the starting value communicated to the function?

```
4.(defun create-list (num)
    (let ((count num)
        (numlist (list num)))
    (lop))
```

Did you mean loop (y or n)? y

```
5.(defun create-list (num)
    (let ((count num)
        (numlist (list num)))
    (loop
        (cond ((equal count 1) numlist))
        <LOOP-ACTIONS2>)))
```

You do want to return the variable „numlist“ here, but just typing it into the code won´t accomplish that. What LISP operator will allow you to return something from a LOOP?

```
6.(defun create-list (num)
    (let ((count num)
        (numlist (list num)))
    (loop
        (cond ((equal count 1) (return numlist)))
        <LOOP-ACTIONS2>)))
```

In numeric iteration the first thing you should do after the exit test is update the counter variable. You can use the function SETQ to do this.

```
7.(defun create-list (num)
    (let ((count num)
        (numlist (list num)))
    (loop
        (cond ((equal count 1) (return numlist)))
        (setq count (1- count))
        (cons)))
```

You’ve got the right idea, since you’ll need to use the function „cons,“ but remember you are trying to insert the new value of the counter into the list. What LISP function allows you to assign the results of this function call to a local variable?

```
8.  (defun create-list (num)
      (let ((count num)
          (numlist (list num)))
      (loop
          (cond ((equal count 1) (return numlist)))
          (setq count (1- count))
          (setq numlist (list)))
```

If you list together arguments like 7 and (8) you get (7 (8)). What you want is (7 8). Try another function that combines things together.

```
9. (defun create-list (num)
     (let ((count num)
           (numlist (list num)))
     (loop
           (cond ((equal count 1) (return numlist)))
           (setq count (1- count))
           (setq numlist (cons count numlist)))))

-----YOU ARE DONE. TYPE NEXT TO GO ON AFTER-----
-----TESTING THE FUNCTION YOU HAVE DEFINED-----

=> (create-list 10)
(1 2 3 4 5 6 7 8 9 10)

=> next
```

Tutorial Communication

Nix (1990) emphasizes that both simple multimedia programs and refined ITSs know what the learner is supposed to learn and determine what he may learn. This does not leave any room for developing creativity. »Whether these uses of computers are a boon, bust, or Big Brother, they are not conceptualized in terms of the type of creativity that is based on unpredictability […] There is room for the type of computer in education where the computer does not and cannot know what you can do with it« (148ff.). The "conversation" with the tutor actually achieved is an exchange of the ELIZA type, not much more than a parody of conversation which does not resemble any kind of natural interaction: »Students communicate with a tutoring system through an interface. These interfaces, given current hardware and software technology, cannot achieve anything approaching the bandwidth of person to person communication« [Reiser (1992), 206)]. Nevertheless, such a form of communication can lead to an indirect devaluation of human interaction, as Ridgway [(1988), 45] has pointed out.

McCalla even reports a rumour that "the LISP Tutor has been roundly condemned for its 'fascist' interaction style (its immediate feedback features often seem intrusive and counterproductive)" (111). Bonar and Cunningham (1988a) give competitors' faults as the reason for their development of *Bridge Tutor*, faults they cautiously express in this way: »PROUST is limited in that it cannot have a rich interaction with the student. The LISP tutor developed by Anderson's group (Reiser, Anderson and Farrell, (1985) is highly directive, forcing a student to proceed in a more or less top-down manner« (391). But BRIDGE itself imagines communication between learner and program in a rather restricted form as well: "The program responds to the student in the guise of 'Gworky' the friendly troll" (399). In other words, the tutor generates syntactically and grammatically correct sentences and puts these sentences into the mouth of a cartoon character – if I am supposed to accept this as pedagogical discourse, it becomes clear that there communication is reduced to a mere exchange of appropriate facts and rules.

In all theses cases, the dialogic structure is not symmetrical, as Petrie-Brown (1989a) states: »The discourse is seen as arising out of the planning of the tutor and as a by-product of tutoring. This model of tutorial discourse generation is extremely misleading as it denies the importance of the language exchange as a negotiation between the participants in a dialogue« (22). It is problematic to apply the term "discourse" to this restricted dialogue between man and program. Petrie-Brown's conclusion is that the tutor would have to be adjusted so that the learner might have aims of his own. This cannot work in my opinion. The fundamental problem of asymmetry cannot be solved by opportunistic corrections in the tutor, because it will never be a serious partner in the exchange of meanings. And there is of course an idea of discourse as instrumental dialogue or strategic and instrumentally rational action behind the concept of the dialogic tutor IDIOT (Intelligent Dialogic Interaction for Opportunistic Tutoring) [s. Petrie-Brown (1989b)].

Knowledge Negotiation

The concept of "knowledge negotiation" has been set out in detail in the contributions to the reader edited by Moyse and Elsom-Cook (1992). The development of this concept was triggered by the observation that there are many domains in which there is not one correct view but a pluralism of perspectives. Moyse (1989) has introduced the term "knowledge negotiation" for this phenomenon, by which he understands above all the necessity of considering multiple "viewpoints". As such viewpoints, he does not merely see multiple representations of the same objects, but rather alternative conceptualizations and structurings of the same objects as different applications of mental models. Representation in the form of mental models is meant to realize the constructivist problematic of situated and knowledge exchange in intelligent tutorial systems. Moyse develops an ITS on the topic of nuclear power stations which has multiple perspectives at its disposal and contains a dialogue component that is supposed to enable "knowledge negotiation". On this basis, Baker (1994) suggests a tutor which will be able to negotiate arguments. His model remains restricted to the domain, however, and only covers communication or learning in so far as the interaction management is involved, i.e. there it lacks metacommunication without which negotiation remains a logical "tit for tat" without any perspective of understanding or communication. Even if the goal of a universal component were restricted to purely cognitive acts, one cold not achieve what the constructivists call an exchange of knowledge and meanings. Symmetrical communication is "negotiation" only in the sense of the equal roles of the partners and positions. This variant of taking up elements of constructivist theory can only be called functionalist.

Empathy and the Hypocrisy of Affective Tutorial Strategies

Research on human tutors has shown that their instrumental strategies are seldom the same, and that the larger part of their interventions is geared towards keeping the learners motivated. Lepper and Chabay (1988) speak of a 35% share of interactions serving this purpose. Lepper and Chabay, who also find that intelligent tutors, apart from neglecting cognitive feedback, also lack motivational feedback, want to develop tutors "that display 'empathy'" (244).

They are generally aware that computers or programs will not be able to supply this ability, but want to fit tutors with an empathy component all the same: »It may still prove informative, however, to ask whether a certain degree of 'empathy' might be built into a computer tutor–to see whether the increased intelligence of current tutors might be harnessed to promote motivational, as well as cognitive, aims« (251). It should be evident that the computer and program do not understand us, but they may pretend to do so. I consider this hypocrisy.[19] Resnick and Johnson (1988) would not agree. They think it entirely legitimate and view it as a constitutive feature of artificial intelligence to assign the role of hypocrite to the computer quite knowingly and methodically, because humans would assign this role to the machine anyway. I must quote the passage verbatim because the sense might be lost if reported in other words: »The purpose of artificial intelligence systems used in education is to interact with natural intelligence systems (humans, that is), and humans, we know, will attribute human-like intelligence to any system that behaves, on the surface, as humans do. This means that interactive AI systems may be able to help learners construct the knowledge *by only 'pretending' to know what the learner is thinking. They can, in other words, 'fake it'* and still be effective learning devices, as long as other aspects of the learning system and broader learning environments provide enough useful material for students' knowledge construction« (162) [my italics, R.S.]. What is the affective, social effect of an ITS' didactics on the learner? Will he not begin to avoid a system that pretends to have equal rights and be as human as himself?

ITS: New Wine in Old Bottles?

Park, Perez et al (1987) ask of IT systems, "Intelligent CAI: Old Wine in New Bottles, or a New Vintage?" Dillenbourg and Schneider (1993) ask the constructivists, "Does the situationist position constitute a new paradigm, or is it just old wine in a new bottle?" (42) Which is the wine, which the bottle? The question seems to be a popular one. Remember the statement by Hodges and Sasnett (1993) quoted in the introduction: "What is new is the packaging". According to Elshout (1992), there is not much to be said in favour of the new ITS packaging for the old problem of instruction: "The promises of the cognitive revolution, of education as a form or artificial intelligence, and of ITS were certainly overrated" (16). We have not come much farther today than Polya (1957), but are clamouring for AI and ITSs. Good computer models of thinking behave like good models of meteorology. But who would expect a

19. On the limitation of ITS models concerning feedback and Fischer and Mandl's (1988) experiment to develop more highly differentiated forms of feedback s. above. Moreover: Weizenbaum's ELIZA [Weizenbaum (1966)] demonstrated very clearly – almost to the point of caricature – that a parody of conversation therapy cannot express empathy. The computer always lacks the dimensions of personal attention that a teacher can supply.

correct weather forecast from such models? In her comparative analysis of IT systems, Rosenberg (1990) reaches the conclusion that there are two gross methodological mistakes (184): »First, ITSs are not well grounded in a model of learning; they seem to be more motivated by available technology than by educational needs [...] Second, positive claims for ITSs are based on testing that typically is poorly controlled, incompletely reported, inconclusive, and in some cases totally lacking«.

Early attempts at intelligent tutors are so primitive that they reduce complex environments and complex navigation to simple rules again. Despite all claims of difference from CBI systems and authoring systems [Kearsley (1987), 21-38, esp. the tables pp. 31, 34], there are still unmistakable similarities between IT systems and the early authoring systems, especially concerning the basic pedagogical model, expository instruction and goal-oriented, tutor-centred learning. Nix (1990) emphasizes this as well: »From the standpoint of technology, the ICAI approach and related 'expert systems' (or, more accurately, 'para-professional' systems) approaches are radically different from the two genres referred to previously, the drill/practice/tutorial and the creative programming approaches [...] In terms of the educational outcome, there are clear similarities to traditional teaching systems« (147ff.).

Most of the examples given to illustrate intelligent tutoring systems are so poor that, in view of the lack of sensible contents, one hardly likes to judge the refinement of the intelligence invested into the experimental design. There is no room for pictures and films in AI programs [Clancey (1989)]: »Everything is discursive words and more words–or worst, pictures supposingly reduced to words. So our experience must be ignored, even though we are constantly experiencing images and referring back to them when describing programs. The promissory note is coming due: The prevalent AI model has no place for dreaming, music, or art. We need a cognitive model that does justice to our everyday experience« (34).

This is the area which David, Thiery et al (1989) pounce on: they are developing an AI system which does not treat pictures as illustrations, but as information within a pictorial research system. This is insufficient, however, since the AI function relates to research or retrieval rather than the processing of pictures in learning. There would have to be methods of understanding pictures in order to reach the goal declared unreachable by Clancey. Midoro (1988) also strives for a fusion of hypermedia and ITS, who in a later study pointedly asks: "Do Hypermedia Systems Really Enhance Learning?" [Frau/Midoro et al (1992)]. This has all very little to do with multimedia. I have included a presentation of IT systems here for two reasons only: not because they are multimedia, but because they are supposed to serve as future bases of hypermedia systems since the more modern systems already integrate multimedia interfaces, or since these systems contain intelligent components which others want to integrate into hypermedia systems. A partial use of subsystems and principles of ITS therefore seems interesting from a didactic point of view: as knowledge bases, microworlds and diagnosis tools.

The most vehement attack on intelligent learning programs (ICAI) was probably launched by Ridgway (1988): "Of course ICAI is impossible … worse though, it might be seditious" is the title of his essay. What is behind this? Ridgway accuses IT designers of using idiosyncratic methods, he thinks it is wrong to separate algorithms from practice, and considers it more sensible to let teachers study the idiosyncratic methods of pupils than to expect the pupils to learn the methods of others; he thinks it sensible to try out a multitude of possible representations in problem-solving, a process that intelligent programs will hardly be able to follow. Problem-solvers use qualitative systems and idiosyncratic labels (metaphors) which cannot be simulated by AI programs. Cooperative interaction is more helpful in problem-solving than interaction with tutorial systems. In his opinion, there are deficits in the following areas: pupil explanations, teamwork and reflection. Ridgway's criticism culminates in the claim that, in spite of these restrictions, IT systems might have damaging consequences, among which he names neglect of teacher education, devaluation of human communication, insinuation of myths (there is a solution to every problem), devaluation of open problems, anthropomorphism.

A possible position in view of these problems is the introduction of "unintelligent tutor behaviour". Several authors speak of "unintelligent tutoring" [Vosniadou (1994)], because of the discontent with intelligent tutoring systems and the desire to arrive at computer-aided learning environments. Vosniadou wants the authenticity and relevance of exploratory environments, which call for a certain openness, while IT systems to her seem too structured and closed: „An Unintelligent Tutoring System, such as the one proposed by Nathan and Resnick, does not try to understand or model the student, as an ITS system does. Rather, through an analysis of the task domain, it reflects the students´performance back to the student in a meaningful way, so that the student can assess it."(14) [cf. de Corte (1994); the idea probably originates in Kintsch (1991); cf. also the idea of minimalist instruction in Carroll (1990)].

The New Position of Constructivism

Clancey (1988a), who developed the tutorial systems GUIDON and NEOMYCIN for medical diagnostics of colds, today understands tutorial systems as a reification of diagnosis and admits that he overlooked the learner. His goal is a student model as a preliminary stage of an apprenticeship concept. Clancey (1989) does not see a way to new improved AI programs, but is in search of tools for cooperative learning. Instead of fixed knowledge structures, he calls for pluralistic perspectives, active production processes, and self-reflection. In a fundamental essay, Clancey (1992) explains his critique of IT systems: »This critique explains why I have not developed ITS programs at IRL in the past five years, and how I am working with social scientists to define and fund research projects in a different way« (22). He is concerned with the programs' relation to real life, with the teaching of abstract concepts within contextual environments. Situated cognition demands a quasi-anthropological approach with multiple perspectives from the users' viewpoint, an approach he calls "socio-technical approach". Knowledge is acquired through interaction with or analysis of the world and other people. Representations of knowledge should not equated with knowledge itself, they are interpreted knowledge. By way of example, he presents the modifications a system like his earlier development NEOMYCIN would have to go through in order to meet the demands of the new approach (26):

»Adopting a global view of the context in which a computer system will be used, versus delivering a program in a computer box;
Participating with users in multi-disciplinary teams, versus viewing teachers and students as my subjects;
Being committed to provide cost-effective solutions for real problems, versus imposing my research agenda on another community;
Facilitating conversations between people, versus only automating human roles;

Realizing that transparency and ease of use is a relation between an artifact and a community of practice, versus an objective property of data structures or graphic designs;
Relating schema models and ITS computer systems to the everyday practice by which they are given meaning and modified, versus viewing models and programs as constituting the essence of expert knowledge, to be transferred to a student;
Viewing the group as a psychological unit, versus modeling only individual behavior.«

Clancey closes his observations with the these sentences, which are worth thinking about:

»I have spent most of the past four years reconsidering the assumptions that directed my AI research. I have concluded that the exclusively individualistic view of cognition as something that occurs inside the individual brains is a useful, but a narrow conception of knowledge […] I have concluded, that as a computer scientist interested in applications programming, I must turn my work upside-down. I must start with the user-environment, not computer science ideas. Rather than developing systems inside a computer lab and delivering to users, I must develop within the context of use. The idea that I could demonstrate a medical instructional program to teachers in a computer science office now seems ludicrous to me« (32).

Clancey (1991) is of the opinion that forms of representation are a product of interaction, and not stored scripts. Greeno (1991) views cognitive processes as interactions with the environment and humans, rather than as operations by way of symbols. Situated learning is fundamentally different from information processing, which sees cognitive concepts as schemata and scripts represented in knowledge. We have forgotten the teacher and neglected model learning [Bandura (1976); Bandura (1986)]. Personality development takes place in a social community. In so far, the constructivism's call to view identity development as part of the growing "communities of practice" [Allen (1992)] points out a correct and important perspective. Constructivism unites learning in conversation and language games [Pea (1992)], learning through discourse, with cognitive learning processes in problem-solving.

Pea (1992) describes this direction as "augmenting the Learning Discourse". With this characteristic, we have recovered something that had been obscured by the long stretch of faceless instructional design programs and patronizing intelligent tutoring systems: a conception of learning characterized by discourse and communication and understanding. American research in this field, regrettably, poses such aims in a very striking, almost metaphorical manner, adding very little in the way of methodology, but it is obvious that constructivism is trying to follow new avenues. One only has to contrast the ritually repeated formula of instructional design and IT systems that learning is "concept acquisition" with Pea's statement, »Learning is fundamentally built up through conversations between persons, involving the creation of communications and efforts to interpret communications« (316), in order to realize: According to the ideas of constructivism, one learns realities and truths mediated and interpreted in communication. It is these that must be understood, not the facts and procedures stored in domain databases by the designer. Learning needs active acquisition processes and constructions (Pea uses the term "appropriation" in Leontjev's sense).

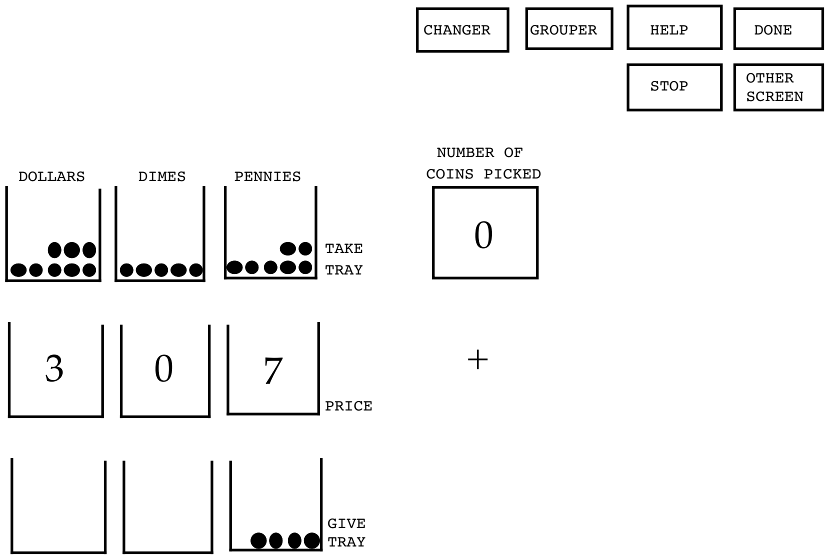
Synthesis of ITS and Constructivism?

There are attempts to mediate between IT systems and constructivist learning environments [e.g. Boder/Cavallo (1991)]. Elsom-Cook (1990) and Elsom-Cook and O'Malley (1990) set this as their aim. Lamontagne and Bourdeau (1992) doubt whether it is at all possible from a methodological point of view: »It would be great indeed if all TS research had to do was to add an environment to its traditionally exclusive student/tutor pair, and if all LE research had to do was to add a tutor to its traditional exclusive student/environment pair [...] But can the fundamental opposition between the two trends be resolved that simply? We think not. The main problem comes from the absence of both an epistemological and a theoretical background to the proposal« (100).

Coinland

Such an attempt can be seen in the program *Coinland* developed by Hamburger and Lodgher (1992), which they describe in an essay with the ambitious title "Semantically Constrained Exploration and Heuristic Guidance" [reprint of Hamburger/Lodgher (1989)]. *Coinland* is a learning program on subtraction for the first three grades. Hamburger and Lodgher claim exploratory learning as well as "cognitive apprenticeship" for their program, and add an element of tutorial systems with "heuristic guidance". The pupils are introduced to coin exchange in the fictive *Coinland* by way of a story, and are then supposed to learn the operation of subtraction with the help of the program. Coloured circles (coins) appear on the screen, accompanied by numerals. The

FIG. 17
Coinland, illustration after Hamburger/ Lodgher (1989)



pupil is to learn to give the correct amount of change. In order to do this, he »navigates around the screen with the four arrow keys, picks up and drops coins with three specially labeled function keys, and uses the ENTER key to select options on the screen« (155). In this example, subtraction is to be learned through playful exploration on the basis of the concept of conservation of quantity: »Conservation of quantity constrains the search space, making it manageable and instructive« (157).

The social context remains extrinsic to the calculation process, a story told before. The coins in the example are pieces of one, ten, and a hundred; for a realistic transposition of the metaphor, the quarters and half-dollars of American currency, or the pieces of five and fifty in European currencies are missing. The screen does not show realistic coins, it formalizes the process and thereby makes it abstract. Any Las Vegas computer game with one-armed bandits has a more realistic representation. Why did the authors not simply realize the topic of "buying and selling" in live social interaction in class with toy grocer's shops? Traditional pedagogics has a large repertory of motivational learning situations that should not be replaced by computer programs. Coinland is an inconsequential translation of an interesting concept that is falsely presented as a constructivist learning environment. The semantic restrictions, moreover, aim at the exact opposite of exploratory learning, namely to make the situation manageable and present it as "instruction". This is dealing in counterfeit coin.

I also find it difficult to understand why comments on unnecessary or overlooked actions in borrowing are called "Heuristic Guidance". What is heuristic about such simple tips – other than the explanation that this simple form of tips and alerts was chosen "because diagnosis is impossible to do perfectly and difficult to do well" (163)? The program may not be bad, but its hybrid pretensions make it implausible. I cannot see this artificial concatenation of completely different elements of learning situations as a legitimate realization of the constructivist approach. In my opinion, classification in terms of theories of learning becomes a mere juggling with names in this case, "cognitive apprenticeship" turns into a mere metaphor without substantial background. Another couple of approaches with too much pretensions, and constructivism need not show its face in school again.

CHAPTER 7

Caught in Petri Nets – Hypertext and Hypermedia

The History of Hypertext

Memex

The advisors of American presidents occasionally have an epoch-making influence on science. In 1945, Vannevar Bush, advisor of President Roosevelt, described a machine for page-turning and making notes with huge amounts of text, *Memex* [the concept goes back as far as the thirties, Nielsen (1995), 33]. With *Memex*, Bush had an analogy between the 'associative' workings of the human brain and the associative networking of texts in view. The vision was never realized, but it did not remain without consequences [Bush (1986); Conklin (1987), 20; Kuhlen (1991), 66ff; Nielsen (1990), 31ff; Nielsen (1995), 33ff]. The idea of hypertext is traditionally attributed to Vannevar Bush, Rayward (1994), however, sees the work of Paul Otlet as predecessor. It became more and more important to follow Bush's vision: The extent of documentation for e.g. military purposes (in 1988, a manual for jet planes comprised about 300.000 sheets, weighed 3150 pounds, and took up a space of 68 square feet) forced people to leave paper behind and explore digital ways [Ventura (1988)]. Ventura reports that the American Ministry of Defence had to exchange five million pages per year (111). Access to information, e.g. to archives of photo agencies, documentations of newspaper publishers, law gazettes, became so difficult that databases were increasingly introduced in order to make information easier to manage and easier to access.

NLS/Augment

Two decades after Bush, but still influenced by him [Nielsen (1990), 35], Douglas Engelbart at the Stanford Research Institute also aimed at widening the scope of human reasoning. In 1968, he implemented the system NLS/Augment (oN Line System) at the »Augmented Human Intellect Research Center«, and invented the computer mouse as input device [Engelbart (1988); Conklin (1987), 22; Kuhlen (1991), 67ff; Gloor (1990), 176ff; Nielsen (1990), 34ff; Nielsen (1995), 36ff]. Augment came into wider use with McDonnel Douglas. This was a large project in which a team of 40-60 persons was to develop a CBT program of 814 hours length [Ziegfeld/Hawkins et al (1988)].

Xanadu

The invention of the term »hypertext« is generally attributed to Ted Nelson, who developed the hypertext system *Xanadu* (the Xanadu Operating Company is a subsidiary of Autodesk, Inc.), [Nielsen (1995), 37ff; Nelson (1967)]. *Xanadu*, whose aim was a networking of the entire world literature, was never fully realized. Nelson already imagined a client-server concept with non-local links, as we have today in the World Wide Web [Nelson (1974); Ambron/Hooper (1988); Conklin (1987), 23; Kuhlen (1991), 68ff; Nielsen (1990), 35ff; Berk (1991) describes *Xanadu*'s client/server model]. The distribution of *Xanadu* was announced by the »Xanadu Operating Company« for 1990 [Kuhlen (1991), 71; Woodhead (1991), 190ff].

KMS

Knowledge Systems' KMS (1983) for SUN and Apollo computers [Akscyn/McCracken et al (1988)] is a derivative of ZOG (1972 and 1975) [Robertson/McCracken et al (1981)], a development of the Carnegie-Mellon University [Woodhead (1991), 188ff]. The first dissertation on the topic of hypertext was probably written about ZOG [Mantei (1982); Nielsen (1995), 44ff]. From 1980 to 1984, ZOG was used to develop a computer-supported management system for the nuclear-powered aircraft carrier USS Carl Vinson [Akscyn/McCracken et al (1988), 821]. KMS was started in 1981 because a commercial version had been requested. KMS is a distributed multi-user hypertext system [Yoder/Akscyn et al (1989)]. It is based on frames which can contain text, graphics, and pictures in various combinations, and whose size is limited to a maximum of 1132 x 805 pixels. In KMS, the author and reader modes are not as yet separated. The reader may edit text, and create new frames and links, which are signalled by small graphic symbols in front of the text, at any time. KMS uses a three button mouse, which can generate 9 different functions.

HyperTIES

The development of Ben Shneiderman's HyperTIES began in 1983 at the University of Maryland. From 1987, HyperTIES was further developed and distributed by Cognetics Corporation [Shneiderman et al (1991)]. HyperTIES appears under DOS as a text system with alphanumerical interface in the typical DOS typeface. The articles function as nodes, and highlighted portions of the text serve as links. Highlighted text appears in bold type on the screen. The developers' puritan philosophy is expressed in the sparing use of links, which were restricted to headings: »We strongly believe that the use of the article titles as navigation landmarks is an important factor to limit the disorientation of the user in the database. It is only with caution that we introduced what we call ‘opaque links’ or ‘blind links’ (a link where the highlighted word is not the title of the referred article), to satisfy what should remain as special cases« [Plaisant (1991a), 20]. HyperTIES only knows unidirectional links, »because bidirectional links can be very confusing« (21). The bottom of the screen offers some navigation commands (Back Page, Next Page, Return to…, Extra).

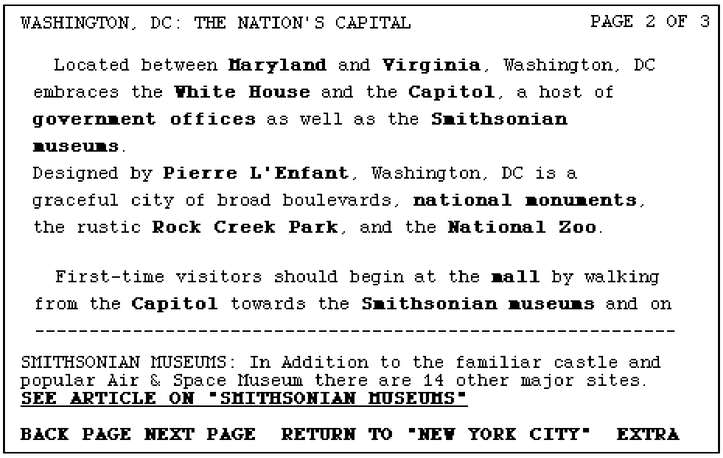


FIG. 18
Screen Shot from Shneiderman (1989), 117

Representative of the system is »Hypertext Hands-On!«, which was published both in book form and as electronic text on a disk, contains 180 articles on the topic [Shneiderman/Kearsley (1989)], and allows the reader a direct comparison of book and hypertext [Nielsen (1995), 45ff].

HyperTIES displays more graphical features in windows systems, thus e.g. in the example of the Encyclopedia of Jewish Heritage cited there (157), which is to contain 3.000 articles and 10.000 pictures on a laser disc, as well as in an application on the Hubble Space Telescope developed in SUN [s. Shneiderman (1989), 120]. But pictures are only stored as backgrounds, and are not inserted into the hypertext environment with integrated links [Plaisant (1991a)]. In the SUN version, one has contented oneself with »tiled windows«, because cascading windows were judged too difficult for beginners. HyperTIES, according to Shneiderman, follows the metaphor of the book or encyclopaedia (156), from which the name TIES (= The Electronic Encyclopedia System) is derived [Morariu/Shneiderman (1986)]. An overview over HyperTIES can be found in Plaisant (1991a).

Although the authoring tool already facilitated some aspects of the automatic construction of hypertext, Shneiderman had to set the individual book pages manually, something which a tool like the *Expanded Book Toolkit* (The Voyager Company) does automatically. The link buttons in the text were positioned individually, and had to be shifted manually after editing processes which made the text shorter or longer. In modern hypertext systems, the buttons cling to the text and do not have to be set by hand in editing. HyperTIES is still in a pioneering stage. But something becomes clear nevertheless: the boundaries between hypertext and the Guided Tour or Kiosk are not clear-cut any longer.

NoteCards

Xerox PARC's *NoteCards* (1985) is a multi-window hypertext system written in InterLisp, developed on Xerox's D-machines which were supplied with high resolution screens. The commercial version of *NoteCards* was implemented on Sun computers, among others. This is already more widely distributed than the systems mentioned before, but Xerox never put *NoteCards* on the market. *NoteCards* follows, as the name indicates, the card metaphor. Each individual node is a data card, but in contrast to the first version of *HyperCard* this has variable windows. Links refer to cards, but are embedded in any place whatever, in addition there are browsers that work like standard cards, and data boxes, special cards on which several cards can be united that work like menus, lists, or maps [Halasz (1988)]. The browser card displays the network in a graphical overview [Conklin (1987), 27ff; Gloor (1990), 22ff; Catlin/Smith (1988); Woodhead (1991), 189ff; Nielsen (1995), 47ff]. The *Instructional Design Environment* (IDE) already mentioned was built on *NoteCards* in Xerox PARC [Russell/Moran et al (1988); Jordan/Russell et al (1989)]. Halasz (1988) had seven wishes left with regard to NoteCards: search and enquiry, composite structures, virtual structures for changing information, calculations via hypermedia networks, version control, support of collaborative work, expandability and adaptability.

Intermedia

Intermedia (1985) by Andries van Dam and the Institute for Research in Information and Scholarship (IRIS) of the Brown University is already a system that is employed in everyday university use and several faculties (biology, English literature) for the cooperative development of teaching materials and for learning in front of the screen. Yankelovich et al (1985) describe the development that electronic document systems have taken at the Brown University. After the exclusively text-oriented system FRESS (1968) [cf. Nielsen (1995), 40] and the *Electronic Document System*, which could already display pictures and graphical representations of the node structure and play animation sequences, and BALSA (Brown Algorithm Simulator and Animator), a true breakthrough was only achieved with Intermedia. Yankelovich, Haan et al (1988) describe the system vividly with the help of 12 screen dumps of a session. Intermedia consists of five integrated editors: *InterText* (similar to MacWrite), *InterPix* (for displaying bitmaps), *InterDraw* (similar to MacDraw), *InterSpect* (displaying and rotating of three-dimensional objects), and *InterVal* (editor for chronological time lines). In addition, Houghton-Mifflin's *American Heritage Dictionary* or Roget's *Thesaurus* can be called directly from *Intermedia*.

Intermedia operates with variable windows as basic unit. All links are bidirectional links of two anchors. *Intermedia* works with global and local maps as starting points for browsers, the WebView window displays the documents and links as mini icons connected by lines [Conklin (1987), 28ff; Kuhlen (1991), 198ff; Gloor (1990), 20ff, 59ff; Nielsen (1995), 51ff]. *Intermedia* version 3.0 was initially sold commercially. But this version only ran under A/UX on the Macintosh [Woodhead (1991), 181ff]. Since this system was not employed very often, Intermedia unfortunately did not enjoy wide distribution [Nielsen (1995), 51].

Guide

Thus these historical prototypes did not become successful commercial systems. *Guide* (1986) by OWL (Office Workstations Limited) was the first commercially successful hypertext system. Peter Brown had started it as early as in 1982 in England at the University of Kent: »To some extent the release of Guide could be said to mark the transition of hypertext from an exotic research concept to a 'real world' computer technique for use in actual applications« [Nielsen (1990), 42; Nielsen (1995), 54ff]. Guide was initially developed for the Macintosh by OWL, later for PCs as well. Of all the systems, it is most strictly modelled on the document. Guide offers text pages, on which text passages can be marked as links with different meanings. The cursor assumes different shapes if placed over those passages and thus alerts the user to the existence of links. Guide knows three kinds of links: jumping to another place in the same document or another document, opening a note-taking window or dialog on top of the current text, and replacing text by shorter or longer text (fold, unfold). In version 2, a scripting language for accessing a laser disc player was implemented.

HyperCard

In 1987, Bill Atkinson's *HyperCard* was published. There were tense expectations before that. Conklin (1987) in his historical overview of hypertext systems even thought the rumour worth reporting: »As this article goes to press, there is news that Apple will soon have its own hypertext system, called HyperCards« (32). One may justifiably claim that no other software, let alone another programming environment, has had such an important influence on the use of computers as *HyperCard* has had. In the literature on hypertext, the historical importance of *HyperCard* is emphasized again and again, although Landow (1992b) is surely right when he describes *HyperCard* and *Guide* as only the »first approximations of hypertext«:

»One system, although not directly a hyper'text', has pushed the original idea to a broad audience: HyperCard from Apple« [Irler/Barbieri (1990), 261].

»Launched in 1987, it is by far and away the most successful hypermedia program launched to date. The fact that HyperCard offered Macintosh programming facilities to complete novices, the fact that it was bundled free with new Macintosh computers, and its general purpose applicability, have resulted in a user base of over a million. It has broken grounds for other hypermedia programs, provoking a huge amount of attention in the press and enthusiasm from users in many different professions« [Woodhead (1991), 174].

»HyperCard is of course only available for the Macintosh range of computers but Apple's marketing ploy of giving a copy of HyperCard away free with every Macintosh has served to make HyperCard phenomenally successful as an application development environment« [Fountain/Hall et al (1990), 299ff.].

»HyperCard™, since its release in 1987, has arguably been the single greatest promoter of interest in hypermedia, and despite its limitations can be used to implement complex and relatively sophisticated systems« [Macleod (1992), 21].

»widely considered the breakthrough hypermedia program which gave computer users unprecedented power to organize and manage information without having to master the cryptic syntax of a computer-programming language« [Perelman (1992), 43].

»The final step to 'realworldness' came when Apple introduced HyperCard in 1987« [Nielsen (1990), 42].

Nielsen (1995) puts the success of HyperCard down not the fact that *HyperCard* was free for Macintosh owners (Fountain/Hall et al; Woodhead), nor to the invention of the most simple programming language in the world (Perelman; Woodhead), but to the seductive effect of the stacks shipped with *HyperCard*, which offered a wealth of graphics, prefabricated buttons, and card designs to the user (62). *HyperCard*, like *NoteCards*, is based on cards. The early versions were only black and white and only knew cards of a fixed size for the 9″ screens of the first Macintosh generation. The first *HyperCard* version did not have any hypertext features. One had to create those by way of buttons and scripts attached to the buttons. Only one window could be kept open at a time. But *HyperCard* had a scripting language which was easier to learn than even BASIC, and at the same time more powerful, because it did not have be written in the form of a program, but could simply be attached to objects on the card. *HyperCard* relieved the developer of event handling and thus allowed for quick prototyping [Nielsen (1995), 58]. The scripting language HyperTalk could also integrate programs written in Pascal or C as external programs, and call them with a single command, which made the programming performance even more powerful. Event handling in *HyperCard* is extremely rich and flexible: thus it is not only possible to trigger a script by clicking a button and then releasing the mouse key, but also when the cursor is in the vicinity of an object or going out of that region, if you hold down the mouse key, or if no user action occurs for some time.

In later versions *HyperCard* received a built-in hypertext function, with the help of which text passages could be marked as hypertext anchors, and a built-in debugger. Today *HyperCard* has two scripting languages, HyperTalk and AppleScript, and is also suitable as an interface for AppleScript programs. *HyperCard* can save stacks as stand-alone applications, and is slowly turning from an interpreted into a compiled environment. For these reasons, *HyperCard* is perhaps the most powerful of the systems discussed here.[20] Kahn (1989) compares *HyperCard*, *Intermedia*, *Guide*, and KMS, and discusses how the respective systems' different features come through in the design of the respective applications.

New hypertext systems are still being developed, partly for experimental reasons, partly with particular function extensions for cooperative working and writing, partly with rather exotic variations of the standard functions:

MORE

The outliner MORE (predecessor: ThinkTank; by Living Videotext, later Symantec) offered hypertext-like functions relatively early (1986), but was restricted to the hierarchic order of titles and subtitles, and had no cross-referencing within the same level [a similar assessment in Nielsen (1995), 11]. Today even word processors like FrameMaker (from version 5), Interleaf (WorldView) or Microsoft Office 98 products offer hypertext functions and can save their documents in HTML format.

Andrew Toolkit

The *Andrew Toolkit* (Carnegie Mellon University) combines a file system (Vice) with a graphic user interface (Virtue) and the CMU Lisp Tutor [Hansen (1988)]. The CMU Tutor is a unit editor for the development of computer aided learning units. According to Sherman, Hansen et al (1990), the *Andrew Toolkit* started out as architecture for Multimedia documents

20. *SuperCard* is a superset of *HyperCard* (Silicon Beach Software, then Aldus, then Allegiant Technologies, now Incwell). I will discuss *AthenaMuse*, one of the big multimedia systems, in greater detail in the section on »exemplary hypertext applications«.

and applications under X Windows, and combines hypertext with hypermedia abilities.

IBIS

IBIS (Issue-Based Information System), better known as *gIBIS* by MCC (Microelectronics and Computer Technology Corporation, Austin, Texas) [Conklin/Begeman (1988)], is supposed to support software design on Sun computers. *gIBIS* supports cooperating groups of software designers in the construction of diagrams, to which hypertext can be added. Nielsen (1995), 73ff describes the further development of gIBIS into the icon-oriented planning instrument CM/1. *Design* by the Meta Software Corporation (1987) works in a similar fashion to *gIBIS*.

Boxer

Boxer allows putting text units into boxes as containers (and putting further boxes with texts into those) [diSessa (1990)]. The boxes can be shrunk to lines or be expanded into windows. *Boxer* distinguishes strictly between text and graphic boxes. The graphic boxes can contain mobile and interactive units. They form the basis of Logo Turtle activities. »However, Boxer is unique in that not only does it contain a programming language, it is a programming language« (305). In this sense, Boxer goes beyond hypertext and becomes a cognitive tool (s. Chapter 10). diSessa talks of »mind toys« and »knowledge spaces« in connection with *Boxer*.

SEPIA

SEPIA (by the GMD-IPSI, Bonn) supports planning and argumentation of cooperating groups in particular [Streitz/Haake et al (1992)]. The graphical browser looks like a project planning chart or a tool for creating tree diagrams. SEPIA's specific feature is that it knows several types of links, and allows collaborative editing of argumentations. SEPIA distinguishes several activity spaces, among them a contents space, a rhetorical space, an argumentation space, and a planning space [Streitz/Hannemann (1990)]. In the planning space, the nodes are called issues, and the links have rhetorical names like e.g. serve, answer and reference. In the argumentation space, SEPIA knows the node types claim, datum, rebuttal and statement, and the link types so, contradicts, unless and reference [Streitz/Haake et al (1992)]. A detailed description of a cooperative planning example illustrated with three screen shots can be found in Nielsen (1995), 91-97. Hannemann and Thüring (1995) illustrate the draft for their own article with a screen shot from SEPIA (30). They distinguish (32) atomic nodes (information units, consisting of text, sound, picture etc.) and composite nodes (aggregates of atomic nodes), structure nodes (composite nodes with references), as well as two types of structural links, sequencing links and exploration links.

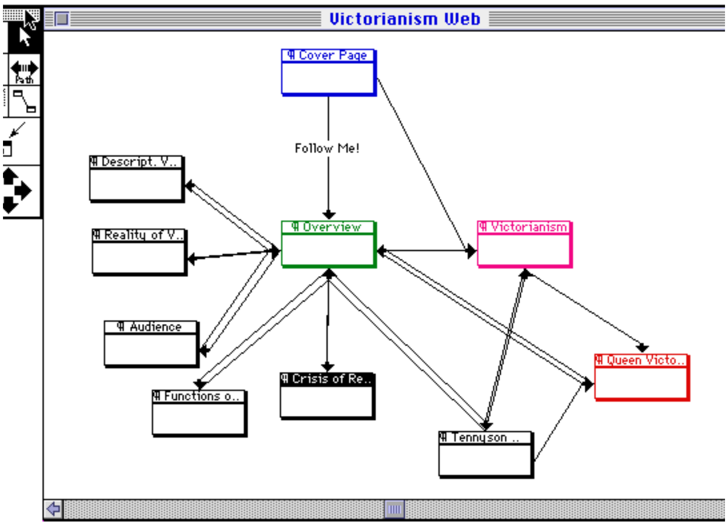
Aquanet

Aquanet by Xerox PARC is another collaborative hypertext tool for the collaborative analysis and arrangement of argumentations, and the representation of knowledge structures[Marshall/Halasz et al (1991)]. Marshall and Rogers (1992) report the attempt of using *Aquanet* for structuring texts for machine translation.

StorySpace

StorySpace, too, is a tool for writing hypertext systems, which shows similarities to outliner programs. The passages are displayed in frames which can be freely arranged and linked with each other as in an object-oriented graphics program. Again like outliner, *StorySpace* can automatically construct a tree diagram out of the entered text passages [Bernstein (1991b)]. Bernstein and Sweeney (1989) have developed »The Election of 1912« as an example [s.a. Garzotto/Schwabe et al (1991)]. Slatin (1992) reports on the »single best experience I have had in 15 years of teaching« (49), an attempt of teaching a seminar on modern poetry by e-mail integrated in *StorySpace*.

FIG. 19
StorySpace -
Hypertext in Frames



AnchorsAweigh

AnchorsAweigh is a hypertext tool resting on *SuperCard*, which allows creating bidirectional links like those in *Intermedia*, and typed links from the user point of view [Brown/Chignell (1993)].

CONCORDE

CONCORDE (CONnected Card-ORienteD Entities, Brunswick) is a system developed with Smalltalk-80 on a SUN that works with linked cards like *HyperCard*, and whose user interface works with the spatial metaphor of neighbouring cards [Gloor/Streitz (1990); Hofmann/Langendörfer et al (1991); Hofmann/Schreiweis et al (1990)].

World Wide Web

Also worth mentioning are the browsers in the World Wide Web, like e.g. Mosaic (CERN, Center for Nuclear Physics Research in Geneva, later NCSA, National Center for Supercomputing Applications) and Netscape Navigator (Netscape Communications), which follow the standard format (HTML) and will have a much wider distribution than all other systems mentioned up to now, because they are free for Internet surfers.

Hyper-G

A possible future rival of the WWW is Hyper-G by the Institut für Informationsverarbeitung und Computerunterstützte Neue Medien (IICM; institute for information technology and computer aided new media) of the Graz Polytechnic[Kappe (1991)]. Hyper-G knows more data types than the WWW, allows full-text search, allows hypertext anchors in pictures and films, has a 3D mode, and supports multi-lingual user interfaces. [A detailed description, with five illustrations, will be found in Nielsen (1995), 200ff.]

Further systems are listed and described shortly in the appendix to the conference volume by Lucarella, Nanard et al (1992).

The first overview over the hypertext concept and individual hypertext systems was written by Conklin (1987). He already listed 18 different hypertext systems (21). Conklin reports that the first promoters of the hypertext concept complained that the computer community showed little interest in their ideas. He supposes that the reasons for the lack of interest was not the then expensive hardware needed for hypertext systems, but that the attitude of computer users had changed in the meantime. If that is correct, the World Wide Web in the Internet will certainly ring in the next wave of the concepts' popularization.[21]

Types and Functions of Hypertext Systems

Kuhlen (1991) distinguishes the following four types of hypertext after the degree in which they use hypertext structures:

- »Hypertext systems or bases with simple units and associative links and associative 'browsing';
- Hypertext systems or bases with structured units and typed links; navigation in the hypertext base is mostly based on the principle of direct manipulation;
- Hypertext systems or bases with structured units and typed links; navigation in the hypertext base can be mostly based on the principle of direct manipulation, but can also rely on author-set paths;
- Hypertext systems or bases on the basis of units structured by knowledge-based techniques and typed links; navigation in the hypertext base is organized on dialogic, cooperative principles« (22).

From the learner's point of view, such hypertext design options can be viewed according to the degree of limitation which they imply for the learner [Wright (1989)]. Legget, Schnase et al (1990) present a »taxonomy« of five classes of hypertext types that takes its classification criteria from the aspect of how much weight nodes and links take up respectively:

21. An overview of the current state of hypertext system is supplied in Nielsen (1990), 87ff. [s.a. Nielsen (1995), 33-66]. Nielsen (1995) contains a comprehensive annotated bibliography on hypertext (365-449). Ramaiah (1993) offers a bibliography with about 300 titles on hypertext in education and training.

Literary — Links are more important than nodes: *Xanadu*, *Augment*, *Intermedia*

Structural — Nodes are more important than links: KMS, gIBIS, *NoteCards*, *HyperCard*

Presentational — Nodes are more important than links, and in addition: authoring and user environment are separated: HyperTIES

Collaborative — Links and nodes both have the same importance: DIF und *Augment*

Explorative — like Collaborative, and in addition: space metaphor for the user interface: *Intermedia* und KMS

The classification of hypertext types varies according to the respective interpretation pattern:

Nelson and Palumbo (1992) distinguish between hypertexts for the presentation of knowledge, hypertexts for the representation of knowledge, and hypertexts for the construction of knowledge. The first type are electronic libraries with author-set paths, the second type explain the relations between nodes, partly with the help of graphical networks, while the third type offers active forms of working to the learner.

Kuhlen (1991) distinguishes hypertext types according to their functions for work or use: Collaborative writing, problem-solving, computer aided planning, literature (hyperfiction), support for software development, technical and online documentation, kiosks in museums (179ff.).

Jonassen (1993) distinguishes five possibilities of employing hypertext in learning processes: hypertext as vehicle for information transport, hypertext as machine for searching for information, hypertext in complex, constructivist learning environments, hypertext in the sense of the cognitive flexibility theory, hypertext for collaborative construction of knowledge.

Gloor (1990) distinguishes between single user and multiple user systems on the one hand, and between idea-processors and storage and retrieval systems on the other hand (5). Learning software and teaching software are found in the category single user/storage and retrieval systems in Gloor, with a distinction between the following types of programs: drill & practice, knowledge mediation, online manuals, and online libraries.

From the point of view of usage, Nielsen (1990) subdivides hypertext systems into computer programs, business applications, intellectual tools, learning programs, and entertainment or leisure programs (45-86).

Nielsen (1995) also cites interactive adventure games as an example for hypermedia systems, e.g. Déjà Vu (1988 by ICOM Simulations) or MYST (1993 by Cyan). But he sees a serious difference between the links in an adventure game and in a hypertext: »I will not classify adventure games as hypertext because they are fundamentally based on making it difficult for the user to navigate to the desired destination and they often hide the clues for the links to other locations in the information space« (12ff.). Structurally, there is no difference between game and hypertext, but there is a difference in the functionality of that structure for the user. Even KIOSK systems which access laser discs are no true realization of hypertext principles in Nielsen's view if they only serve as triggers for playing film clips. Nielsen stresses these differences because he thinks the »look and feel« are more important than defined structure.

How can hypertext be used at universities? Kuhlen (1991) distinguishes the following possible uses in university teaching:

1. »Hypertext as a means of orientation in the courses of study on offer, but also as a means of an academic institution's self-portrayal (part of university marketing);
2. Hypertext as didactic support of presentation of knowledge by the teachers;
3. Hypertext – in the extended approaches of computer-supported education ('computer-based training' – CBT) as interactive and non-linear possibility of self-study […]
4. Hypertext as a means of learning by modelling, acquisition of knowledge through the construction of hypertext bases on selected curricular subjects« (186).

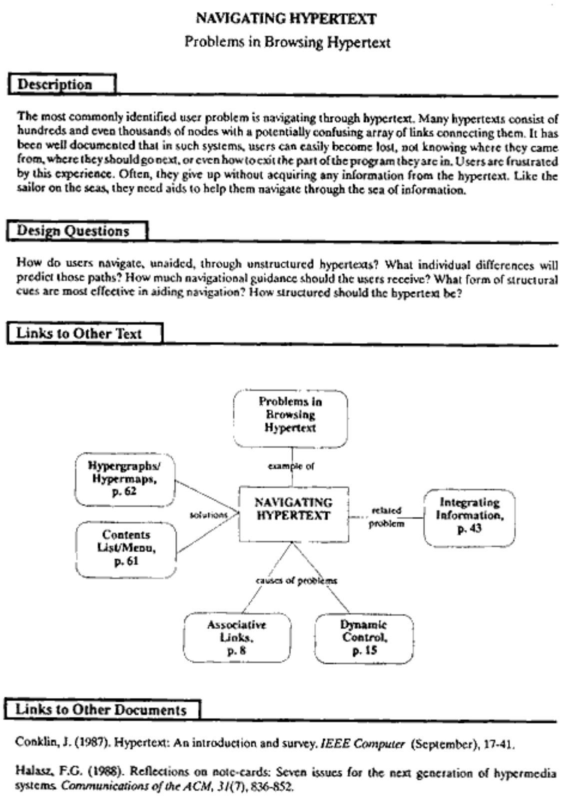
Exemplary Hypertext Applications

In 1988, the Association for Computing Machines (ACM) dedicated an issue of »Communications of the ACM« to reprinting six articles which had been presented as papers at the Hypertext '87 Conference. The same articles were also published in various hypertext formats, with *HyperCard* for the Macintosh by the Institute for Research in Information and Scholarship (IRIS) of the Brown University, with HyperTIES for IBM PCs by the University of Maryland, with KMS for SUN-3 Workstations by Knowledge Systems, Inc., and with *Guide* by OWL for Macintosh and IBM PCs.

These variants allow an effective comparison of the performance and construction features of the respective hypertext systems, although the comparative analysis by Alschuler (1989) suffers from the assumption that the effectively realized forms of links and paths are features of the respective environments that say something about the quality of the developing environments. That is not the case, however. The realized forms go back to design decisions of the programmers, who could have had the opportunity to install other indirect and direct links, cards, indices and search possibilities. The systems compared offer more variance to the programmer than was realized in the examples, especially the systems that have a built-in programming language. The variations (e.g. pictures of the authors in *HyperCard*, comments in HyperTIES, sub-headings in KMS) do not say anything about those systems, because in principle all of them would have been possible in all three systems. What becomes clear in all three examples, however, is that the conversion of sequentially argued presentations, that is linear texts, into non-linear environments does not make for very convincing results. Alschuler reports a conversation with Shneiderman, who was in charge of the HyperTIES version: »Ben Shneiderman told me that his work on Hypertext confirmed his suspicion that this type of 'linear' text could not be translated into hypertext« (358).

An original attempt of »re-translating« hypertext into book form was made by Jonassen (1989). He published texts on hypertext both as a *HyperCard* stack and as a book, with the book structured alphabetically by titles, and with references to related terms or sections with page numbers at the end of each section. The two following illustrations show a page from the book and a card from the stack. The book page is subdivided into title, a description of the title, and a section with a diagram of the linked terms with page numbers. In the book, one must turn to the respective page, in the stack, there are several possibilities of navigation: one can click on the respective term in the diagram or the text, or on the navigation buttons below the card.

FIG. 20
Page from the hypertext book by Jonassen (1989)



NAVIGATING HYPERTEXT

Problems in Browsing Hypertext

Description

The most commonly identified user problem is navigating through hypertext. Many hypertexts consist of hundreds and even thousands of nodes with a potentially confusing array of links connecting them. It has been well documented that in such systems, users can easily become lost, not knowing where they came from, where they should go next, or even how to exit the part of the program they are in. Users are frustrated by this experience. Often, they give up without acquiring any information from the hypertext. Like the sailor on the seas, they need aids to help them navigate through the sea of information.

Design Questions

How do users navigate, unaided, through unstructured hypertexts? What individual differences will predict those paths? How much navigational guidance should the users receive? What form of structural cues are most effective in aiding navigation? How structured should the hypertext be?

Links to Other Text

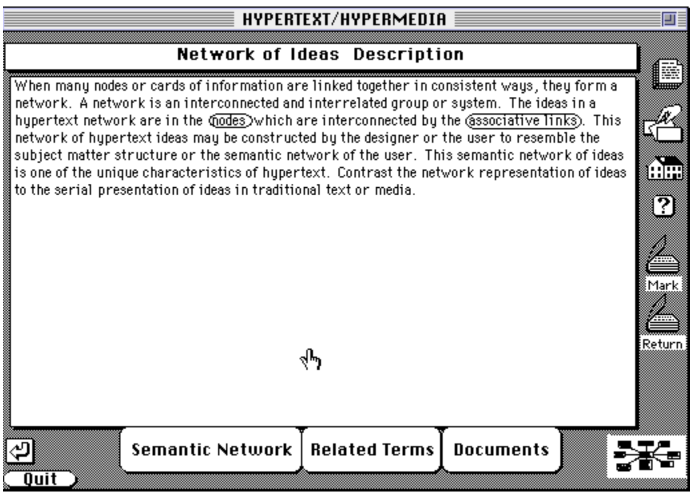
Problems in Browsing Hypertext
example of
Hypergraphs/ Hypermaps, p. 62
Contents List/Menu, p. 61
solutions
NAVIGATING HYPERTEXT
related problem
Integrating Information, p. 43
causes of problems
Associative Links, p. 8
Dynamic Control, p. 15

Links to Other Documents

Conklin, J. (1987). Hypertext: An introduction and survey. *IEEE Computer* (September), 17-41.

Halasz, F.G. (1988). Reflections on note-cards: Seven issues for the next generation of hypermedia systems. *Communications of the ACM, 31*(7), 836-852.

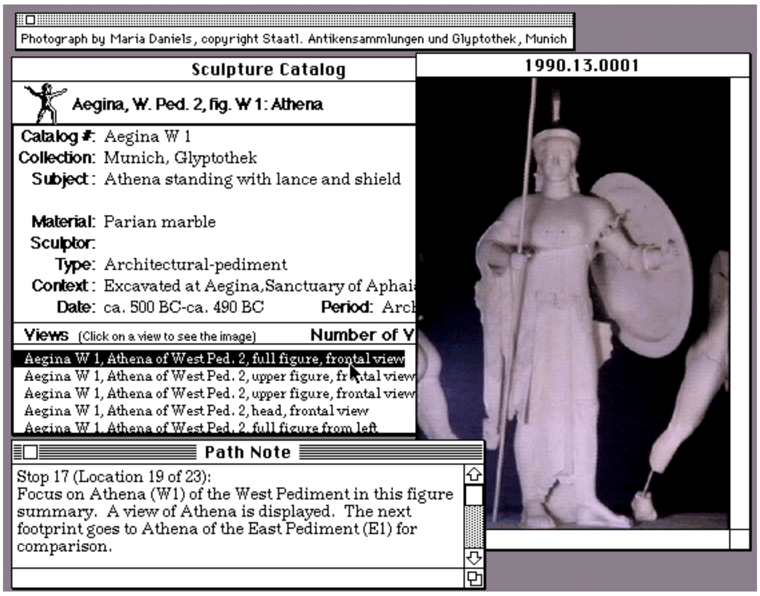
FIG. 21
Card from the *HyperCard* Stack by Jonassen (1989)



INTERMEDIA: Application Examples

The two hypermedia environments that have probably had the greatest ideal influence next to *HyperCard* on the development of this type of software are *Intermedia* and *AthenaMuse*. Interesting applications were created with the help of each, which were used for teaching at their respective universities. This is especially true for Intermedia, while some examples developed in *AthenaMuse* have remained prototypes.

FIG. 22
Screen Shot from
Perseus (*Intermedia*)



One of the most comprehensive examples from *Intermedia* is *Perseus* (Harvard College) [Crane/Mylonas (1988); Mylonas/Heath (1990); Mylonas (1992)]: in 1991, the system consisted of CD-ROM and laser disc, and ran on a Macintosh under HyperCard. The second version was released in 1994 and already comprised several CDs. The CDs contain the data, the laser disc all pictures and films. The system is navigated from maps; it contains texts in the Greek original and their translation, encyclopaedias, dictionaries, and pictures of classical works of art. The system is a cooperative product of many researchers. The users can make notes, edit paths, and make comments.

Landow (1989b) describes the use of *Intermedia* in English literature teaching [s.a. Landow (1992b)]. He gives a detailed account of some projects on the works of individual authors of world literature which were created through student work in seminars.

Context32

These projects were collected under the title *Context32* [Launhardt/Kahn (1992)]. The author and his assistant provided about 300 texts, 500 pictures, and 40 timelines initially. The students put together a great variety of documents and a wealth of thematic and media aspects on the various topics in the seminar. In 1989, the system contained a corpus of 2000 electronically networked documents [Landow (1989b)]. Some parts of Context32 were later taken out as special subsets, e.g. the *In Memoriam Web* on a poem by Tennyson, and a collection of texts on emblematics [Launhardt/Kahn (1992)].

Context34

Context34 is a further attempt of Landow's in connection with a course on English literature. The collection started as small web and was then augmented by the students [Launhardt/Kahn (1992)]. In this case, *Intermedia* was mainly used as authoring tool for the students. Launhardt's and Kahn's article lists many further examples on social sciences, political science, philosophy, history of religion, Chinese literary history etc.

Dickens Web

Some environments created under Intermedia became independent later on. The *Dickens Web*, material on Dickens and his novel »Great Expectations«, was later realized as a system-independent hypertext application under *StorySpace* on the Macintosh and under *WorldView* by Interleaf on the SUN [Landow/Kahn (1992)]. Kahn and Landow report on a comparative evaluation of the three versions by 15 hypertext users. What they found most irritating was the page metaphor in Interleaf's *WorldView*.

The *Biology of Plant Cells* is a collection of *Intermedia* documents [Yankelovich/Haan et al (1988); Launhardt/Kahn (1992)]. In the »Program for Liberal Medical Education«, *Intermedia* serves as tool for students of medicine for organizing and coordinating their work [Launhardt/Kahn (1992)]. One *Intermedia* collection is dedicated to »Shakespeare« [Friedlander (1991)].

One is certainly justified in saying that the hypertext materials with the most comprehensive contents and best planning have been developed with *Intermedia* up to now. It is particularly regrettable therefore that this project was no longer supported after 1991: »even though Intermedia was the most promising educational hypertext system in the early 1990s, it does not exist any more« [Nielsen (1995), 54].

ATHENA: Application Examples

Athena is already more of a multimedia or hypermedia system than Intermedia. It takes its starting point in the concept of learning environments and cooperative learning processes. Hodges and Sasnett (1993) stress the constructivist basic ideas which were behind the development (32). The authors describe the *AthenaMuse* project with excellent colour illustrations and many black-and-white pictures for the various projects developed with *Athena* [cf. Hodges/ Sasnett et al (1989)]. *Athena* is object-oriented and knows a scripting language, EventScript. *Athena* is based on a »compound document« architecture (191ff.), which is created with the help of so-called »plastic editors« (165ff.), dynamically modifiable editors, which are themselves organized like complex documents. Each document has several dimensions. This technique goes far beyond the standard of data definition and tool development for multimedia that had been reached at the time, and has still not been surpassed by the market development, e.g. the Hotspot technique for automatic link detection, and the pursuit of polygon regions in video films [s. Michon in Hodges/Sasnett (1993), 219ff.].

With *Athena* , several applications in five different fields have been developed, all of which put considerably less stress on the hypertext character than the Intermedia project, but rather emphasize the multimedia type through their strong orientation towards picture and film sequences. The students can take an active part in all examples, e.g. record notes, rearrange pages, take snapshots of a walk and cut them out, add text etc. For Hodges and Sasnett, this creative role offered to the students is already sufficient evidence for classing *Athena* with constructivism (32).

Hodges and Sasnett put the application examples (73ff.) into six groups [a list of the projects can also be found in Michon (1992), 370ff.]:

Virtual Museums	Chronoscope (Musée d'Orsay), Smithsonian Image Collection System, Harvard Scientific Instrument Collection, Man Ray Paris Portraits, Seeds of Change
Simulations	Language learning (Direction Paris: A la Rencontre de Philippe and Dans le Quartier St. Gervais for learning French; No Recuerdo for teaching Spanish); Navigation Visual Learning Environment; CERN Diorama
Analysis Tools	Film Analysis with Alfred Hitchcock, Environmental Literacy, Women's Roles in Developing Countries, Film Analysis with Citizen Kane, Project DOC Edgerton, Media Literacy Curriculum, Boston Suburbs
Editors	Color Palette, Font Editor, Attribute Editor, Video Editor, MuseBuilder, Subtitle Editor, Object Editor, Action Editor, Pixmap Editor
Information Management	GTE Real Estate Project, AthenaMuse Mail Agents, The Meeting Analyzer, Quality Design Toolkit

Electronic Books

Neuroanatomy Learning Environment, Engineering Geology Education, Mechanical Bearings, Biology, Bibliothèque de France, AthenaMuse On-Line Documentation.

Hodges and Sasnett give a detailed description and explanation of the design principles and navigation possibilities for the navigation of sailing boats, the tour of the Parisian *Quartier St. Gervais*, the picture database on *Man Ray*, as well as of the electronic books:

Dans le Quartier St. Gervais

The multimedia tour through the Parisian Quartier St. Gervais was developed by Schlusselberg and Harward (1992) for the Modern Language Department of the M.I.T. The quarter is initially displayed as a street map. From the map, 29 locations in the quarter can be accessed directly. But the quarter can also be explored through »surrogate travel« from a stroller's perspective like in the *Aspen Movie Map*.

Individual buildings in »Dans le Quartier St. Gervais« are arranged as links to other short film clips. More than 600 historic pictures offer an additional historical dimension to the 29 locations. A historic guide explains what the student sees on his tour. As soon as one steps into a shop or building, a film is played, and speakers appear in interviews. Subtitles can be displayed for the films, and by clicking on a word in the subtitles, a dictionary is called up on the screen. The contents of the interviews are also available in the form of lists of topics.

The authors see in »Dans le Quartier St. Gervais« an example of discovery learning: »We call it a set of materials that enables students to participate, explore and discover a 'world of knowledge'« (108). Further descriptions on »Dans le Quartier St. Gervais« will be found in Murray (1992), Murray/Malone (1992), and Evelyn Schlusselberg [in Hodges/Sasnett et al (1989), 103ff.].

A la Rencontre de Philippe

»A la Rencontre de Philippe« is a further example of multimedia foreign language teaching, a strongly branching film in the form of a tree structure, arranged as simulated interaction with fictitious people, which starts out from a street map arranged as »surrogate travel«. In contrast to »Dans le Quartier St. Gervais«, this example has an additional fictitious story between Elizabeth and Philippe, which is supposed to stimulate discovery learning [Murray (1992)]. Elizabeth's and Phillippe's apartment is also arranged as a map that allows surrogate travel [Murray/Malone (1992)]. Both stories contain additional interactive simulated objects, such as a copy of Figaro with flat advertisements, and a telephone with which one can dial numbers leading to a simulated answering machine. Murray and Malone give a more detailed description of the method by which the fictitious time in the narrative structure of both applications was calculated.

Navigation of Sailing Boats

The project »Navigation Visual Learning Environment« [Hodges/Sasnett (1993), 89ff.] is an example for the principle of »surrogate travel«, a simulated journey. The application simulates sailing in an area of two square miles of coastal waters before Maine with the help of 10,000 pictures that were arranged as panorama views at angles of 45°. The interactive and almost real-time simulation occurs in seven dimensions (position of the boat in x,y, direction of the boat, speed, viewing perspective, and compass with two dimensions). A trip to shore through the rocks and the flora at the seashore was also integrated into the system. The initial design envisioned 700,000 knots, which would have required 5.6 million pictures for the simulation of a movement by 4 yards. That was impossible. One had to make do with intervals of 50 to 200 yards. This of course provides a problem for the users and the interpretation of the environment: »A common mistake in the design of surrogate travel systems is to underestimate the need for continuity from one point to the next and not provide enough context at each point: the result is that users lose their orientation« (95).

Engineering Geology Educator

The »Engineering Geology Educator« (140ff.) comprises more than 1000 pictures of geological features and processes. The textbook of 236 pages is arranged in the form of an encyclopaedia, as a single page with 236 items: »The sequential organization of the pages in Geology can be viewed as an atavistic feature carried forward from its paper-based forebears« [Michael Webster in Hodges/Sasnett (1993), 141]. The electronic book on Neuroanatomy(142ff.) is organized differently. It comprises 1400 individual text documents in no fixed sequential order, and an archive with pictures and films of the brain. The texts are linked to each other and to picture libraries by way of three indexes of varying levels of abstraction (alphabetic, neuroanatomical structure, brain functions): »This is a fundamental break from the normal structure of a book« (143). The cross section pictures of the brain are stored as films and linked to each other by way of a virtual space so that zooming and scaling appears to be possible in quasi-3D. But it is not a true 3D solution [cf. the 3D solution on anatomy in Höhne/Bomans et al (1992)].

The examples on Man Ray's Paris Portraits [Hodges/Sasnett (1993), 117ff.], CERN Diorama (127ff.), and on the Boston Architecture Collection [Davis (1992)] belong to the multimedia type »Virtual Museum«. Boston Suburbs is basically a picture database with various views and manipulation possibilities for the pictures.

Davis (1992) reports on further *Athena* projects, Turkle (1992) on controversies, mistakes, and failed plans of the physics institute involved. A German development of the universities of Kaiserslautern, Karlsruhe, and Freiburg that is modelled on *Athena* is NESTOR [Mühlhäuser (1989); Mühlhäuser (1992)], a hybrid authoring system in combination with components from instructional design and hypermedia elements.

Further Examples

The imagination of authors of books on hypertext with regard to the question of which fields of application might be suited for hypertext seems to be limited. Most mention documentations, encyclopaedias, and online help. The catalogue in Nielsen (1995) is somewhat more comprehensive: online documentation, user help, software engineering, service manuals, encyclopaedias, auditing, law, trade shows, organization of ideas, journalism, research, foreign language learning, museums, libraries, and games. But he is still missing a whole range of sensible application possibilities. For this reason, I will in the following discuss some applications which each have a particular aspect to add to this range. It is also remarkable, especially in comparison with the minimal domains of the instructional and tutoring systems, what a broad range in the spectrum of fields these systems already occupy. The examples may serve to demonstrate three current trends:

- In some examples, the hypertext foundation is partly obscured behind the multimedia surface, i.e. hypertext is only used as a method of organization and navigation for information that does mostly not consist of textual information (e.g. medical tutorials).
- In other examples, hypertext and other program types are mixed, e.g. games, simulations, experiments.
- Still other examples try to incorporate components from instructional design and the field of intelligent tutoring systems into hypertext environments.

Who Built America?

A very comprehensive and interesting hypertext example is a CD-ROM on the history of the USA from 1876 to 1914, »Who Built America?« [Rosenzweig (1993); Voyager Company]. The CD contains 5000 pages of text, 700 pictures, and 60 diagrams, 4 hours of audio, and 45 minutes of video. The system partly follows the book metaphor. Margin notes can be made in the book, and a separate notebook can be opened. But the book is only the smaller part of the system: more than 200 »excursions« from the book are offered. More interesting than these figures, however, is the choice of contents for »Who Built America?«. »Controversial« topics from American history such as mob law, race riots, the emergence of the women's movement, the problem of abortion, and the awakening of the homosexual movement are not passed over in this historiography. The selection is perfectly suited to the presentation of pluralistic views and to stimulating discussion on those topics in school or at university. For a time, Apple Computer shipped this CD with computers for schools. Apparently due to protests of abortion opponents in the US, Apple has regrettably revised this decision [electronic communication from the authors].

I am usually bored by applications that take the computer itself or topics from information science as their subject. But what I found interesting is a tutorial designed with *HyperCard* on the technical structure of a computer using a concrete example [Knieriemen (1989)] which displays the computer itself in the form of graphical hypertext. The components of the computer's architecture become nodes by way of which the computer can be opened up and viewed from the inside.

StrathTutor

With the *StrathTutor* , Mayes, Kibby et al (1988) developed a hypertext that is supposed to be particularly suited to guided discovery learning [s.a. Kibby/Mayes (1993)]. Mayes (1992b) calls hypermedia systems like the

StrathTutor cognitive tools. Elsom-Cook (1988) considers how discovery learning might be supplemented by guiding tutors in an interactive computer aided learning system.

Writer's Pocket Almanack

Brockmann, Horton et al (1989), who developed the *Writer's Pocket Almanack*, with *HyperCard* giving them opportunities beyond hypertext for the integration of a game into the hypertext environment, report the wanderings and wrong tracks which after various experiments with databases, word processors and layout programs finally led to the development of a hypertext system.

Some hypermedia systems attach external laboratory apparatus like microscopes, ECGs and such. Others simulate such an attachment by accessing databases with x-rays, sonograms, spectroscopic data etc.

A hypertext system for molecular spectroscopy was developed at the ETH Zurich [Cadisch/Gloor et al (1993)].

The universities of Ulm and Munich developed a multimedia tutorial for medical sonograms [Kuhn/Rösner et al 1992].

MEM

MEM is a hypermedia system for computer aided basic and further training in the field of memory psychology [Glowalla/Hasebrook et al (1992); Glowalla/Hasebrook et al (1993a); Glowalla/Hasebrook et al (1993b)].

IEN

IEN (Individualized Electronic Newspaper) is an attempt by GMD-IPSI to have individual newspapers automatically generated in a hypertext environment[Hüser/Weber (1992); cf. NewsPeek by the M.I.T., s. Brand (1987)].

PathMAC

PathMAC is an application for pathology constructed with *HyperCard* and *Guide* by the Cornell School of Medicine [Diaz (1991)] that contains texts and slides, allows simulated laboratory experiments, and presents case studies.

Water Videodisc

The *Water Videodisc* is a multimedia program on water physics which was developed by the Open University in cooperation with the BBC [Bolton/Every et al (1990)]. An ecological exploration of a nature reserve, arranged in the form of surrogate travel, the *ECODisc*, is from the same cooperation.

Grapevine

Grapevine is an example developed with *HyperCard* on the history of the USA in the thirties from the perspective of Steinbeck's »Grapes of Wrath«, which offers laser discs with music, interviews and films in addition to text [Campbell/Hanlon (1991)].

MuG

MuG, the »Multimedia Guide to the History of European Civilization«, is Umberto Eco's attempt to realize his literary fantasies from Foucault's Pendulum in a multimedia system [Eco (1992)].

Plaisant (1991b) describes a »Guide to Opportunities in Volunteer Archeology« developed with HyperTIES which was supplied with a touch screen as a museum kiosk (but which suffers strongly from HyperTIES' lack of graphical features).

Giellman (1991) describes a multimedia database on Pompeii with a KIOSK-like surface. From this database grew an exhibition project of the city of Naples which could be seen in the US and many European cities. On 11 of 15 computers, the visitor could view various parts of the database per touch screen, which belonged to different parts of Pompeii.

Holmes (1991) describes the »Electronic Music Lover's Companion« developed by him under *HyperCard*, a guide to classical electronic music that combines different kinds of text with music samples and pictures.

The setting of a medieval monastery serves Thomas (1991) as metaphor for a walk through a medieval library written with *HyperCard*. »If Monks had Macs…« combines the imitation of Christ with Gregorian chant.

The Bughouse [Gay/Mazur (1991)] combines anthropology, art, history, and entomology.

Francl (1993) describes *Nematode Glossary*, a hypertext glossary for seminars on nematodes. The definitions of the anatomical terms are linked to colour illustrations.

The Hereward College, a National Residential College for handicapped students in England, is also the site of the National ACCESS Centre. With the support of the Nuffield Foundation, it offers electronic books for physically handicapped students who cannot use normal books [Page (1991)].

Book House

Book House is a Danish hypermedia system for libraries [Pejtersen (1993)] that bases the links mostly on the features of the respective domain, which are symbolized through icons and pictures.

Further Examples

Jacques, Nonnecke et al (1993) evaluate 16 stacks created with *HyperCard* with regard to purpose, contents, structure of nodes and links, method of navigation, control mechanisms, and style of presentation. They present the differences by way of five examples which are meant to be representative for the rest: a motorcycle learning program with animation, an argumentative text on the assassination of Kennedy with dramatic use of sound, a CD-ROM on Shakespeare's life and times with the play *Twelfth Night*, the program *Celtic History Museum*, an example of a virtual museum, and an introduction to *Microsoft Excel*. A number of further applications are described in the appendix to the conference volume by Lucarella, Nanard et al (1992) by way of short abstracts with names and addresses of the authors: a multimedia history of the universe, a hypertext on the history of physics, *Ecoland*, a prototype for environmental awareness education, a hypertext for Japanese teaching, a KIOSK for the Horne Museum in Florence. I will mention further examples in the chapter on KIOSK systems.

A Borderline Case

A somewhat curious system is the hypermedia system *Alexandria*, named after the Alexandria library founded by Ptolemy II but destroyed in a fire [Russel (1990)]. *Alexandria* is a conglomeration of learning materials or resources, which are either instruction units or tools, and which are called and controlled from a common core. This core was initially developed in the *DIE Interpreter* and later under *NoteCards*. It consists of four modules: *Instruction Problem Solver*, *Instructional Unit Selector*, *Instructional Unit Applier*, *Student Model Update*. The core's task is to develop a learning schedule for the student, suggest learning objectives, and select units. In addition, it supplies the following: protocolling of student actions, instruction tutor, navigation help, coordination of resources. So far the concept seems familiar: it is an instructional design borrowing a few features from intelligent tutoring systems. What about this system earns the name of hypermedia? The resources are small microworlds, simulations in STELLA, programmed instruction, encyclopaedias, video library, syntax-checker, and databases. Like a MultiFinder, the core program takes care of calling the resources which are considered to be instruction units. *Alexandria* is also a mixture of instruction and intelligent tutor, with media, programs, and dates. Russell presents it in a conference on hypermedia systems, although the title of his presentation names the genre much more precisely: »A Learning Resources Management Architecture«.

Hypertext in Networks

Most knowledge on school and university experiments in networks is no longer gleaned from books, but from the Internet itself, and this more often than not by way of tools based on the hypertext concept, like e.g. *Mosaic* or *Netscape Navigator*. All institutions that run networks or are in charge of them, foundations and research institutes which deal with the evaluation of networks, are represented there with databases, reports, and World Wide Web servers, so e.g. the Consortium for School Networking (CosN), the National School Network Testbed [http://copernicus.bbn.com], the International Society for Technology in Education ISTE [http://iste-gopher.uoregon.edu], EDUCOM, the educational association for the use of computers at US universities, or TECFA, the institute »Technologies de Formation et Apprentissage« of the University of Geneva in Switzerland [http://tecfa.unige.ch], and finally the GNA, the »Global Network Academy«, which offers support for all suppliers of online courses [http://uu-gna.mit.edu]. Since 1993, there has also been a journal dedicated especially to the use of computers in school networks in NetTeachNews. One of the experiments on a broad base which have really made headway for the use of computers in US schools, is ACOT (Apple Classrooms of Tomorrow), about which many experience reports by teachers have been published [s. Sandholtz/Ringstaff et al (1992)]. Collis (1995) gives an insight into various school projects with networks. Pea and Gomez (1992) probably offer the most comprehensive overview over networks between schools, projects sponsored by commercial companies, and future plans in this area. The report is illustrated with a great number of examples. Pea and Gomez stress the wealth of information and the active role of learners in learning in networks.

If one sees hypertext as an alternative to authoring systems from an education theory perspective, the attempt to make *HyperCard* 'even more easy' through a mechanistic authoring component, reduce it to an authoring system, and supply it with functions of response analysis, acting under the assumption that one has to offer simple software to authors, must seem absurd [found in this form in de la Passardière (1989)].

Structural Features of Hypertext

There is plenty of literature on the hypertext concept [excellent Kuhlen (1991); most recently Nielsen (1995)], so that I can immediately pass on to the description of the methodical components of hypertext systems. Schoop and Glowalla (1992) distinguish structural (nodes, links), operational (browsing), media (hypermedia) and visual aspects (iconicity, effects). I will go into these in more detail in the following.[22]

Non-linear Text

Hypertext is also called non-linear [Kuhlen (1991)] or non-sequential text [Nielsen (1995), 1]. Reading a hypertext is similar to switching between book text, footnotes, and glossary: »Therefore hypertext is sometimes called the 'generalized footnote'« (2). Hypertext systems consist of texts whose individual elements (terms,

22. Bryan (1993) describes international standards for exchangeable multimedia and hypermedia scripts, among others: HyTime (Hypermedia/Time-Based Structuring Language, ISO/IEC 10744: 1992), DSSSL (Document Style Semantics and Specification Language), SPDL (Standard Page Description Language) for printers, and SMSL (Standard Multimedia Scripting Language). The guidelines of the Office Document Architecture (ODA, ISO 8613, (1988) are not not of much use for design as long as the ODA extensions for interactive documents are relatively limited [Brown/Cole (1991)]. And not all hypertext concepts are based on a document structure like *Intermedia* or *Guide*, but on database principles. In what ways hypertext systems access information units is the subject of discussions about indexing and retrieval, topics I do not want to treat here. As a pointer to the wealth of possibilities, I will just briefly refer to some examples. Lucarella and Zanzi (1993) organize the retrieval of text with an inference machine; Croft and Turtle (1993) develop a probabilistic retrieval model; Dunlop and van Rijsbergen (1993) design a hybrid retrieval concept that describes contents like a cluster analysis.

statements, sentences) are linked to other texts. The term hypertext mirrors its historical development, because one initially indeed only envisioned pure text systems. Today, however, texts can also be linked to data in a database, to pictures, films, sound and music. Therefore many authors now speak of hypermedia rather than hypertext, in order to stress the multimedia features of the system. Perhaps Nielsen's (1995b) position is sensible; he calls all of these systems hypertext on the basis of their construction principle, because it does not make sense in his view to retain a special term for text-only systems (5).

Hypertext is text in the first place, a text object and nothing else. Text turns into hypertext when a structure of anchors and links is superimposed on the text. One can hardly discuss whether the relation of the text modules is already a non-linear one, or whether non-linearity is only constituted through the links. In any case Nielsen's (1995) assessment applies, »that hypertext is fundamentally a computer phenomenon [...] hypertext can only be done on a computer, whereas most other current applications of computers might just as well be done by hand« (16). Landow (1992c) mentions literary works that have realized similar structures on paper.

A hypertext consists of blocks of text objects; these text blocks represent nodes in a network; navigation from node to node, the so-called »browsing« is managed by way of computer-controlled, programmed links. Landow points to analogous ideas of the French structuralists Roland Barthes, Michel Foucault, and Jacques Derrida, who even used similar terms in their terminology (nodes, link, network) as they are used in current hypertext technology (1ff.). Decisive for the constitution of the network is the size of the text blocks designated as nodes, the »granularity« or »grain size« of the information units. Nielsen (1995) explains by way of the example of a KIOSK application that merely serves to play film clips from a laser disc, where hypertext starts for him: »The reason this design is not hypertext is that the user had no way to interact with the video clip once it started playing. In other words, the granularity of the interaction was too coarse to provide the user with the feeling of being in control and able to explore an information space« (14).

For the network of hypertext, Landow (1992c) has coined the terms intertextuality and intratextuality (38). The term intertextuality [s.a. Lemke (1992)] has stimulated Sager (1995) in turn to create the term »Semiosphäre«: »The semiosphere is a globe-spanning conglomeration consisting of texts, sign systems and symbol complexes, which are, even if they are largely self-contained, still comprehensively networked in the manner of a system, and are thus coherent, non-linear, and both thought- and action-provoking« (217). Sager reports on multimedia hypertexts in the field of history of art, which are connected to video cameras in far-away museums over a network. The hypertext users can remote-control the cameras from their position (planned in the European Museum Network). Sager also mentions the project »Piazza Virtuale« at the Documenta 9, in which TV viewers can put in comments into a hypertext in a live transmission. In this manner, globe-spanning spaces are created which point beyond the application and can incorporate other contents depending on the users' respective interests (224).

Depending on the kind of nodes and links, access to information can be free or restricted in a hypertext [Lowyck/Elen (1992), 139]. In an open environment, the user makes all decisions on access and navigation, in a closed environment, these decisions are made beforehand by the designer. In any case, there may be tensions between the ideas of the users and those of the designer. From the conception of the text blocks, their intertextuality, semiotic patterns can result [Lemke (1992)] that can be used as art forms. The discussion on semiotic or narrative structures of hypertexts is only in its very beginnings, however. Thiel (1995) distinguishes a monologic form of organization for hypertexts from a dialogic one (45), which can establish a kind of conversation mode.

Information Units versus Contextualization

In segmenting texts into text blocks, the question arises whether there is a 'natural' division of text blocks into information units. In this context, the idea has surfaced whether it might be possible to define the text blocks' form and size as cognitive units, so-called »chunks of knowledge« [Kuhlen (1991), 80ff.]: »The 'chunk' concept does not really provide any decisive help for the intensional definition of informational units« (87). Kuhlen refers to Horn (1989), who has employed the chunk concept most consistently, and who distinguishes between four principles for the segmentation of information blocks: chunking principle, relevance principle, consistency principle, and labeling principle. »From this short discussion of cognitive units and their cohesion, we may deduce the insight that neither size nor content of an informational unit can be determined absolutely « (88).

Granularity

A division of the text units into too large segments may run counter to the hypertext principle, i.e. the user will not even realize that he is dealing with a hypertext. Lowyck and Elen (1992) describe this form in drastic terms: »When larger pieces of information are given the hypermedia environment is used as an integrated pageturner and audio or videoplayer. When hypermedia would be used instructionally a highly branched version of programmed instruction is offered. This kind of instruction does not stem from a cognitive but from a behavioristic background« (142). A segmentation into too small information units on the other hand could lead to an atomization of information that may affect the user's cognitive reception: He cannot make out any connections anymore, he cannot »understand«. The different hypertext systems foster the one or the other side of this problem, depending on whether they are based on the database concept or card principle (small units), or whether they prefer an organization into documents (larger units).

The node is not always the basic unit, there may also be nodes of a smaller size within a frame or window, e.g. a word, a sentence, a paragraph, a picture. This differentiation points towards one of the basic problems of hypertext, which is referred to in hypertext terminology as the problem of granularity. That granularity is a thing not easily decided upon (along the lines of »the smaller the better«) is demonstrated by a study of Kreitzberg and Shneiderman (1988). They compare two hypertext versions in a learning experiment, of which one has many small nodes and the other few large nodes. The authors do come to the conclusion that the version with the smaller nodes produces better results, but Nielsen (1995) argues plausibly that this result is probably due to a special feature of HyperTIES that does not apply to other hypertext systems: »One reason for this result is probably that Hyperties is one of the hypertext systems that links to the beginning of an article and not to the location within an article where the information of interest for the departure point is located. Because of this feature, Hyperties is most easily operated with small, focused nodes dealing with precisely one issue so that there can be no doubt about what part of the node a link points to« (137ff.).

Contextualization

Atomization of information can be counteracted by an intensive contextualization of the chunks. Kuhlen (1991) discusses this strategy by way of examples from *Intermedia* (200). A contextualization that is meant to prevent atomization must not only consist of rich contexts within the system, as in the Intermedia examples, but must also be ensured by the entire educational context, as in the constructivist experiments on cooperative learning in social situations [Brown/Palincsar (1989); Campione/Brown et al (1992)].

Narrative Structures

Lave and Wenger (1991) and McLellan (1993) see another means of emphasizing connections in hypertext in stories, in narrative contexts. Stories have a topography, and spatial and temporal dimensions. Bruner (1992) distinguishes ten features of narrative that might also be constituents of hypertext. Stories embedded in hypertext could show a motivating effect especially for the affective dimensions of learning, as the concept of the computer as theatre [Laurel (1991)] demonstrates, whose dramatic models of narration affect the emotions and involvement of the users. Gay and Mazur (1991) consciously employ narrative elements in their program »El Avión Hispano« for foreign language learning. Initially, it was even meant to belong to the »mystery« genre. In order not to have the students stick too much to the model in writing, they made some scenes ambiguous on purpose to enforce a mental distance on the part of the students. Narrative elements (»storytelling«) and a case-based method of instruction [Riesbeck/Schank (1989)] can serve to counteract decontextualization, as Edelson (1993) demonstrates by way of the example of the program CreANIMate, a learning environment with a laser disc which »narrates« examples from the animal world in the form of videos as soon as the learner hits upon a question in conversation with the tutor for which the program knows an example. At the time of the report, no evaluation had been conducted as yet, but the students' enthusiasm is mentioned. The positive reaction of the students is however probably less due to the program or the interactive laser disc technology, as Edelson supposes, but rather to the effect of the fantastic film examples from animal life.

Another example based on the method of case-based narrative is SPIEL (Story Producer for InteractivE Learning) by Burke (1993). SPIEL is a multimedia environment for educational stories, which also conducts the conversation with the student as tutor, diagnoses the student's reactions, and selects and presents the educational interventions. Burke describes YELLO, an example with 200 stories on the topic of »advertising in the yellow pages«, which was developed with this technology. The program runs as simulation. SPIEL calls up a story in a suitable situation. The technology introduces each story and concludes it. The tutor's strategies comprise the following methods: *Demonstrate opportunities, demonstrate risks, demonstrate alternative plan, warn about hopes, warn about fears, reinforce plan, warn about assumptions, explain other's plan, explain other's perspective*.

Nodes and Links

Nielsen (1990) distinguishes three levels of hypertext systems with a view to examining in more detail what possibilities there are for conversion between or standardization of different systems: The level of presentation (= user interface, 110ff.), the abstract hypertext machine (HAM = nodes and links, 111ff.), and the database level (107ff.) [s.a. Nielsen (1995), 131]. The abstract hypertext is the point at which transitions between the various systems would have to be created through appropriate conventions: »The HAM is the best candidate for standardization of import-export formats« (132). Two structural elements should not, however, be standardized in my opinion, the facultative separation of authoring level and user level, and the basic unit of the hypertext system, because they make for creative variety.

SEPIA

While most hypertext systems neatly distinguish between the authoring level (HAM) and the user interface, the hypermedia system SEPIA is a tool for constructing arguments whose users work permanently in the authoring level. Hannemann and Thüring (1992) describe this authoring level as »activity spaces«, of which SEPIA provides the following: the rhetorical space, the planning space, the argumentation space, and the contents space (123).

The basic unit for the hypertext presentation is the frame in KMS, the article in HyperTIES [Shneiderman et al (1991), 146], the card in *HyperCard*, the document in Intermedia, and with World Wide Web systems usually the page or document. In *HyperCard*, there is the additional basal unit of the stack above the card, and on top of that *HyperCard* itself. A stack can also function as node in *HyperCard*. Thus there are systems with one level or with several levels, and there is the difference between systems with static frames (e.g. KMS or *HyperCard*) and those with movable windows (e.g. *Guide* or *Intermedia*, *Mosaic*, and *Netscape Navigator*).

Hypertext systems consist of »anchors«, »nodes« and »links« [Schnupp (1992), 58, 134]. The relations or links which are permanently »wired« in the program are also called »paths«. The structure of anchors, nodes, links, and paths is also called network or »web«. »Web« is the designation for collections in *Intermedia*, e.g. *Dickens Web*. The term »web« has become popular through the World Wide Web in the Internet. The network of links as such is usually not visible in hypertexts. The user only sees the current node. There are however systems which represent the network in graphical form. The hypertext network is supposed to correspond to the cognition psychology hypothesis of being helpful for the creation of semantic networks in the heads of the users [Conklin (1987), 37].

A hypertext link connects two nodes, of which one is the starting or anchor node and the other the destination node. Nodes can be examples, annotations, literature, other titles, pictures, sounds, or film clips. The connections between the nodes, the links, can assume different meanings, depending on the respective context. Gloor (1990) distinguishes hierarchical links, which take up the basic structure of a hypertext, from cross references, which create relations in the texts below the level of the main nodes, and from annotations and comments, which represent additional nodes for the text (16). One only has to compare the link types in *Guide* with those in SEPIA, which are meant to make the argumentation structure more transparent, in order to realize what variety and diversity are possible in this sector. Iconic buttons and graphical user interface elements are common as means of node representation and navigation. Anchors and links are usually signalled by buttons or highlighted text in hypertext. Irler and Barbieri (1990) criticize the choice of buttons for navigation and instead implement a method of calling up pop-up windows with links and placing coloured markers beside the text in a Toolbook system [basically Bier (1992)]. One of the most striking visual features in some hypertext systems is the varying appearance of the cursor, which assumes different shapes in going over the hypertext node buttons depending on the type of the respective link.

HamNoSys Editor

I will illustrate the graphical hypertext technique by way of the example of the *HamNoSys Editor* for sign language developed for the Institute for German Sign Language and Communication of the Deaf at the University of Hamburg. The editor serves to transcribe signs in the symbolic notation HamNoSys (Hamburg Notation System) which is needed for research purposes of sign language linguistics. The notation is complex, and to enter it by way of the keyboard is very awkward and time-consuming. In order to facilitate this task, I have developed an editor working solely with graphical elements which uses hypertext elements in a very idiosyncratic way: The nodes in the editor are pictures exclusively (pictures of hand shapes and movements); the links are jump addresses which carry out a concatenation of individual transcription elements according to grammatical rules of sign language linguistics.

The user proceeds as follows in transcribing a sign: He selects a picture by clicking on it with the mouse (e.g. a particular hand shape), the editor generates the corresponding transcription string in HamNoSys and then jumps to the next part of the editor scheduled for the transcription process by the grammar of HamNoSys (e.g. palm orientation, location head, movement). The HamNoSys notation appears in a field at the top of the screen.

FIG. 23
HamNoSys Editor:
Visual Anchors and
Nodes

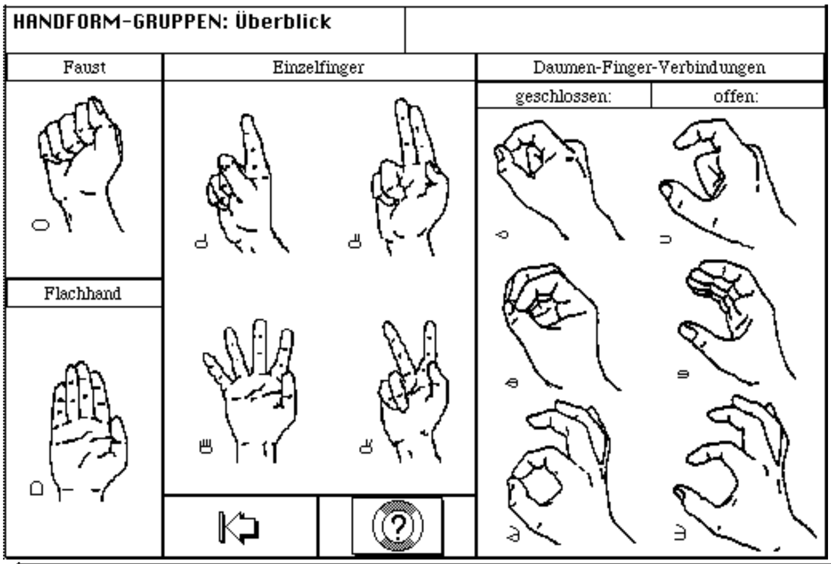
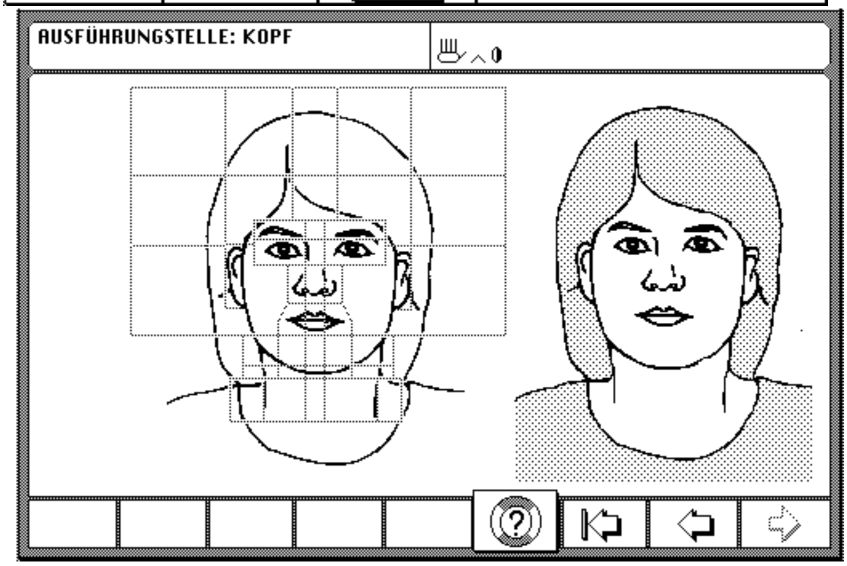


FIG. 24
HamNoSys Editor:
Location Head



The editor's structure is modular and makes up a hybrid system with a polyvalent tree structure. The pictorial elements selected by the user represent the nodes in the sense of hypertext technology. A special feature of the hypertext concept realized with this editor, apart from the exclusively graphical realization of hypertext, consists in the editor's 'generation' of a transcription string according to grammatical prescriptions. Hypertext systems do not only present existing data, they can also generate data. I have also realized the principle of a program that can generate data on the basis of user actions in the program LernSTATS for learning statistics, to which I will come back in the chapter on interactive learning programs.

Types of Links

Most links are implicit, i.e. preset links which– even if they carry a specific attribute, so-called »typed links« – do not make their attribute clear to the user. But there is also the possibility of assigning a label to the respective type of link, so that the user can recognize and work with it. Kuhlen (1991) distinguishes referential or associative links, as well as explicitly semantically or argumentatively specified typed links (34). The reason given is an alleged similarity to memory and associative reasoning processes, the justification is, however, somewhat weak: »We cannot give any further evidence here, but are rather arguing intuitively« (99).

The links in hypertexts can assume a highly varied status with regard to form and contents. They can represent logical or causal, statistic or probabilistic relations. Rao and Turoff (1990) distinguish between convergent and divergent links (12 types), and between different types of nodes (summary, observation, issue, detail, collection, proposition). They provide a concept framework that orientates itself by Guilford's model of the structure of intelligence, and discuss and compare 16 hypertext systems with regard to those points of view: Boxer, CONCORDIA, DOCUMENT EXAMINER, EUCLID, gIBIS, *Guide*, HyperTIES, *Intermedia*, KMS, NEPTUNE, NLS/Augment, *NoteCards*, TEXTNET, THOTH-II, WE, *Xanadu*, ZOG. Trigg (1983) had already proposed a sophisticated taxonomy of 75 typed links in 1983 (e.g. abstraction, example, formalization, application, simplification, refutation, support, data). Parsaye, Chignell et al (1989) distinguish between navigational and semantic relations. Navigational relations are move to links, zoom links, pan links, view links, and index links; semantic relations are antonym, instrumental, causal, and final relations. DeRose (1989), who distinguishes 12 types of links by way of the example of a hypertext version of a bible, recognizes extensional and intensional links; he subdivides the extensional ones into relational (associative, annotative) and inclusive links (sequential and taxonomic) [cf. Kuhlen (1991), 105]. McAleese (1992) distinguishes the following types: being, showing, including, using, causing, similarity. A comprehensive overview of typings and descriptors for links and relations in hypertext will be found in Allen's and Hoffman's (1993) article on *SemNet*. *SemNet* is a cognitive tool for editing networks. Depending on which node is activated, the direction of relations and typing varies. The problem of descriptors for hypertext relations is bound up very closely with the search for primitives, the minimal number of semantic descriptors through which relations in hypertext may be typed. The meaning of the link depends on the respective domain and environment, i.e. it will look completely different in a narrative hypertext than in a hypertext environment for cooperative argument like SEPIA. The search for primitives for relational typings can therefore never be destined to succeed in my opinion. But they might have a useful function for learning: for one thing, typings can demonstrate to the learner what cognitive relations are conceivable, and support thinking in relations in the active construction of links, and for another they can 'channel' the learner's interpretations. Between these two poles, compromises must be found.

Structures of Links

The ensemble of links may follow certain structural concepts. Basically, several different or even alternative models for the network of nodes are possible: *inductive*, *deductive* [Jonassen (1989); s.a. Shirk (1992)], *cohesive*, *modular*, *hierarchical*, and *multi-thematical* [Wright/Lickorish (1989); s.a. Shirk (1992)]. Thus e.g. Canter, Rivers et al (1985) characterize four different structures of user navigation following the graph theory: *paths*, *cycles*, *loops*, and *spokes*. *Paths* are routes that do not cross any node twice, *cycles* bring the user back to the exact point of departure, *loops* are cycles that may not contain any other cycles within themselves, *spokes* are paths that retrace the same route which they took in going out. The link structure can be adaptive in addition to this, i.e. the index can be modified by querying the user and can be statistically adapted to the users' queries, as the NASA's documentation system CID tries to do [Boy (1991)]. Creech, Freeze et al (1991) discuss how one could leave the selection of data and information to the user by the creation of links.

Calculation of Links

Most links are automatic in the sense that on clicking a node (text block or picture), the program jumps to a certain destination by way of the preset link. Kibby and Mayes (1993) designed another principle in their *StrathTutor*: The links are calculated during run time. Therefore an adding or deleting of nodes cannot have any averse effects. The links are 'half-intelligent'. Each node has a number of attributes that can be selected by the author from a set of 60 attributes for the current domain [Mayes/Kibby et al (1990)]. On being clikked, the node calculates which attributes best meet the reader's interest and jumps to the node that best represents this combination. Mayes and Kibby value this technique for its flexibility and call the product »dynamic« hypertext [The *StrathTutor* itself is sketched in more detail in Mayes, Kibby et al (1988)]. Grimes and Potel (1991) discuss the pros and cons of three methodical possibilities: a. indexing everything (which they do not regard as practical); b. no indexing at all, but merely ad hoc searching (they criticize the time factor, and that the method may not be sufficient for the user); c. laying down only the most probable paths (51).

Decisions about the structure of links depend on perspective (the author's, the reader's) or on the structure of the subject matter and theme. It is probably of no avail to search for cognitive concepts like those demanded by the instructionalists in this context, for a cognitive architecture, as Shirk (1992) does: »One is left with questions about the best ways to replicate and create cognitive architectures within hypermedia instruction« (89). Quite apart from the fact that 'hypermedia instruction' is something of a contradiction in terms, it is more feasible to develop something in the manner of a »rhetoric« of hypertext [Landow (1989a)].

Graphs, Maps, and Fish Eyes

Different methods are on offer for the user's orientation in hypertexts. The classic way of a table of contents or menu is not sufficient for most applications. A large part of the hypertext developers' imagination and creativity is invested into the development of different forms of browsers and graphical means of orientation and navigation. This characterizes the surface appearance of hypertext so much in part, that this statement seems justified: »So when asked whether I would view a certain system as hypertext, I would personally not really rely so much on its specific features, command, or data structures, but more on its user interface 'look and feel'« [Nielsen (1991), 4]. Jonassen, Beissner et al (1993) have studied this whole field of graphical methods of knowledge presentation and described it comprehensively. I can therefore restrict myself to just a few aspects.

Knowledge Maps

Nodes and links in hypertext have an inner metre. Botafogo, Rivlin et al (1992) speak of criteria like centrality, compactness, and breadth. This metre can be used by hypertext systems to automatically generate graphical overviews of the respective hypertext application's structure.[23] Stotts and Furuta present a hypertext model which they represent in the form of a Petri net [s.a. Stotts/Furuta (1989)]. Some developers try to exploit these possibilities as means of representation [Collier (1987); Utting/Yankelovich (1989)]. Such

23. e.g. *Intermedia* and *NoteCards*. A tool that automatically generates lists of contents, indexes, but especially local and global maps for navigation in *HyperCard*, is *StackMaker* by Hutchings, Carr et al (1992). An application on the biology of cells developed with *StackMaker* is described in Hall, Thorogood et al (1989).

graphical depictions, insofar as they realize a semantic relation to the hypertext nodes, are called »knowledge maps«, a representation of knowledge structure in the form of diagrams [McKnight/Dillon et al (1991)]. Such knowledge structure diagrams or tables of contents in graphical form do not any longer contain typings or descriptors for links as a rule, and are therefore regarded by Allen and Hoffman (1993) as the »most stingy form« of solving the problem of link typing: »Perhaps the most parsimonious approach to relational descriptors is to leave links unlabeled. The result is generally known as the concept map« (277). The automatic generation of paths belongs to the compulsory exercises for hypertext developers in Kuhlen's (1991) eyes: »In future, pragmatically designed systems should also be able to compile and offer ad hoc calculated paths according to an analysis of the information needs that can be seen to emerge. The problem of coherence will certainly not become any easier to solve through these demands for dynamic paths« (89). Graphical representations can depict networks and paths either two-dimensionally, in hierarchical formation, or three-dimensionally. The example of Arents and Bogaerts (1993), who display the table of contents of their »Active Library on Corrosives« in the form of a three-dimensional cube [s.a. Marvin Minsky's »The Society of Mind«], points towards the limitations that graphical browsers encounter in this context.

Three-dimensional Browsers

Shum (1990) goes back to Neisser (1976) and Downs and Stea (1973) for an example of navigation in hypertext in order to explain the function of cognitive maps and spatial cognition. Downs and Stea distinguish between locations and attributes, and – within these categories – between distance and direction, descriptive and evaluative information. Shum interprets these concepts with regard to hypertext. He discusses different concepts of space, Euclidean, 3D with layers, virtual space. The illustrations show trial realizations in a hypertext environment. Glenn and Chignell (1992) characterize so-called cognitive and visual landmarks: visual designators for navigation and location make the cognitive designators visible. A graphical browser with 3D navigation [s.a. Chapter 2], which utilizes a helicopter metaphor, is presented by Fairchild, Poltrock et al (1988). The method apparently is so complex that the authors made a video so that one might understand the written description [Fairchild/Poltrock (1986)]. Caplinger (1986), who developed a graphical browser for a database of 45,000 objects, reports on problems with 3D navigation. The browser did not seem to be functional for zooming into depth without additional hardware support. Apple Computer has however achieved this with a three-dimensional browser Project X (codename: Hot Sauce) for the World Wide Web that can move more than 100,000 nodes in animated space:

FIG. 25
Apple Computer´s *Project X* for the World Wide Web

Video films are used for a special graphical browser in *AthenaMuse*. The designers of the *AthenaMuse* project have developed a special method for linking subtitles and video which allows the coupling of texts to videos in several dimensions [Hodges/Sasnett et al (1989)]. *AthenaMuse* also already realized the technique of »HotSpots« in films, and their linking to text or program [Michon (1992)]. Navigation with images and films however still depends on preset links with this method. The next step would be the current calculation of links from images and films. There are still some problems here, however, which have to do with the current state of image processing research: »The state of the art of automated image processing leaves little hope for getting, even in the middle term, image processing tools for the computation of semantically interesting links between images. Thus, computing links according to image descriptions stored in the database is the only possible choice« (517), Aigrain and Longueville (1992) say. Exceptions in this regard are images that are based on homogeneous models, or computer-generated 3D images whose shape is known to the computer. One example of this is the navigation in the 3D-Atlas of the human brain by Höhne, Bomans et al (1992) [cf. Pommert/Riemer et al (1994)]. Developers are faced with a similar problem as with the image links calculated ad hoc in the search for simple methods of calculating links from data which are dependent on time, e.g. from pieces of music and films.

Knowledge maps, graphical browsers, and knowledge structure diagrams can relate to the graphical representation of hypertext nodes on the one hand, but can also represent the semantic relations of hypertexts to real world phenomena [Potter/Trueblood (1988)]. This is the case in hypermedia programs on geographical, local, and similar phenomena, which provide suitable space maps as browsers for a virtual stroll through a city or a building. The modes of representing the outer world have not been sufficiently studied in this context up to now.

Lidwell, Hobbins et al (1991) have arranged an interesting variant of a knowledge map in HAKCS [reported in Nelson/Palumbo (1992)]: The knowledge domain from the field of physics is displayed in the form of diagrams. As soon as the students have demonstrated through active creation of relations between subnodes that they have mastered this knowledge area, the subnodes collapse into a single complex node. The reverse process, the viewing of parts of a network with the help of wide-angle lenses, »fish-eye views«, is proposed by Furnas (1986). They serve to see details of data sets or tree diagrams as well as program editors enlarged, zooming in to a detail, so to speak, with the detail's environment being kept in considerably smaller scale in the margin around the detail [s.a. Saxer/Gloor (1990)].

Evaluation

By now, we have the first evaluation studies on the effect of graphical browsers or knowledge maps in hypertexts:

Stanton and Taylor (1992) tested the addition of a diagram as navigation instrument with a *HyperCard* application on the topic of »selecting employees«. First, the navigation ability of the test subjects was tested, then they had to construct a diagram of the stack. No significant differences were found between the two test conditions (12 students each with and without a map; the bad design of the stack and the small scope of only 42 cards may however be responsible for this result). Despite this result they think themselves justified in drawing the conclusion that diagrams as navigation help lead to weaker performance, less use of secondary links, a more poorly perceived control over the system, and worse reproduction of cognitive cards.

Kenny (1991) also tested the usefulness of graphical organizers. The result is typical: No significant differences were found. But the conclusions are typical as well: Further studies with larger samples are necessary.

The exact opposite result was found by Barba (1993) in her experiment with a *HyperCard* stack on the topic of »volcanoes« [s.a. Barba/Armstrong (1992)]. With 143 students as test persons and a pretest-posttest design, clear differences between those students who were provided with an »instructional map« and those that had to work without it could be seen. Not all students profited from the embedded visual information to the same extent, however: the »verbal ability« that was also ascertained proved to be an interesting distinguishing factor. For students with low verbal ability, the visual information was of greater use. If one looks at the map provided by her, one will notice that this offers not so much navigational functions as a structuring of the subject matter through verbal categorizations. It its feasible, therefore, that this instructional map introduced not so much visual navigation, but rather a verbal meta-strategy of learning, which would make the result of the study plausible.

Another study pointing towards the relevance of verbal skills for hypertext navigation is the one by Reynolds and Dansereau (1990), who realized a double, isomorphic representation as a hypertext version with explanatory texts on statistics, and as a hypermap version with the help of knowledge maps in their program MacStat on univariate statistics. The maps contain the text within nodes and graphically represent the relations between the statistical methods. Unfortunately, the sample was not suitable for evaluation. But the data provide some indication that verbal abilities, measured with the »Delta Reading Vocabulary Test«, constituted a difference in the two test groups. The group with the hypermaps was also more content and showed less frustration.

Jüngst and Strittmatter (1995) deal with the structural representation of knowledge from a psychological point of view. Jüngst (1995) found in an experiment with representations of knowledge structures that a higher retention factor is achieved. The result was not as unequivocal under elaborated conditions. The study sample was too small, however, to be able to draw final conclusions.

Reader and Hammond (1994) compared two conditions in an experiment with a *HyperCard* application: One group of students was provided with a concept map, the other group was only allowed to take notes. Better results were achieved by the students with the concept map. But they also spent more time with the tool, probably because they were more strongly motivated. This is not saying anything against the tool, but against the structure of the experiment, which may have generated an artefact in this way.

Browsing or Navigation

I have already discussed the basics of navigation in hypermedia systems in Chapter 2. There is nothing left to say except to add some concrete suggestions on the design of hypertexts in this regard.

Canter, Rivers et al (1985) distinguish five navigation methods: scanning, browsing, searching, exploring, wandering. McAleese (1993b) distinguishes navigation methods in analogy to the learning strategies known from learning research. Kuhlen (1991) distinguishes, rather following the structural features of hypertexts, the following forms of browsing (128ff.):

- Directed »Browsing« with »Take-along« effect
- Directed »Browsing« with »Serendipity« effect
- Undirected »Browsing«

- Associative »Browsing«.

It is clear that the classification of navigation methods in hypertexts depends on the author's respective interpretation pattern. The emphasis can be on the hypertext structure, on the learning methods aimed at, or on the work processes that are meant to be carried out with the hypertext tool. Two questions emerge from this:

1. How do the different navigation concepts affect the design of hypertext?
2. How do the different navigation methods affect the learners? I will make some remarks on this question in the following sections of this chapter.

Kuhlen (1991) divides the means of navigation into conventional meta-information and hypertext-specific means of orientation and navigation:

- conventional meta-information is made up of non-linear means of orientation and navigation, tables of contents, indexes and glossaries (134ff.);
- hypertext-specific means of orientation and navigation are made up of graphical overviews (»browsers«), networked views (»web views«), author-defined means of overview, paths and trails, guided tours, »backtrack« functions, dialogue histories, retrospective graphical (individual) overviews, reader-defined points of reference (»book marks«), author-defined guiding signs (»thumb tabs«), marking of areas already read (»breadcrumbs«) (144ff.).

Apart from the means listed quite comprehensively by Kuhlen, cognitive maps [Bieber/Wan (1994); Edwards/Hardman (1993), 91] and special means of managing permanently wired or user-defined paths [s.a. Gay/Mazur (1991); s. Gloor (1990)] also belong to the navigation-supporting means. Bieber and Wan (1994) propose several forms of backtracking, they especially differentiate backtracking according to whether navigation was carried out by switching windows or by clicking a text anchor [on the function of backtracking see Nielsen (1995), 249ff.; Kuhlen (1991), 156ff.].

One should see navigation in a hypertext environment not only from the angle of its orientational and interactive function, but also as an active form of learning and working. This perspective on the structural elements of hypertext may be the more important one from the user's or reader's point of view: For the designer, nodes and links are in the foreground, but for the reader it is user-defined paths, notes, annotations. These structural objects offer a chance for active working and producing with hypertext.

Notebooks, tools for creating individual links and paths, and for constructing individual cognitive maps, integrated spreadsheets, and direct access to databases are regarded as means that support active learning and working in hypertext [on annotations for Intermedia s. Catlin, Bush et al (1989)]. Neuwirth, Chandhok et al (1995) have built a feature for making annotations into their PREP-Editor. Similar to annotations are popup fields or popup windows with read-only information, which only stay open as long as the mouse key is held down [Nielsen (1995), 142ff.]. Annotations which can be added by the user himself, windows for making notes, can support the reader's active processing. An alternative to annotations are margin notes which do not add anything to the text corpus as such, but can be utilized by the user. The University of Liverpool's MUCH program (Many Using and Creating Hypertext) [Rada/Wang et al (1993)] even offers learners a tool for the creation of individual thesauri. The students can use link types like »used-for«, »narrower-than«, and »related« for connecting the entries.

Interfaces

The structural elements of a hypertext must be able to assume a visual quality, they must be clearly distinguishable from their context in order to be able to catch the reader's attention, and they should also make the structure, e.g. links and nodes, transparent to the reader. Visual elements of the user interface with operational function (navigation) must be distinguished from functional control aspects here. Kahn, Peters et al (1995) by way of the example of an analysis of *Intermedia* and *StorySpace*, elevate such visual signals to the status of 'three fundamental elements of the visual rhetoric' of hypertexts: »These three fundamental elements are:

- link presence (which must include link extent),
- link destination (which must include multiple destinations),
- link mapping (which must display link and node relationships)« (167).

There are still no conventions for displaying nodes and links in the text. Some programs use bold type for sensitive text passages, so that bold type cannot be used in the text for other purposes. Other programs settle for underlined text. Some programs display text as framed when clicked, others again invert the selected text.

It is conspicuous that hypertext systems surround themselves with icons and metaphors that more or less consistently constitute small iconic »worlds«. I have already gone into this in some detail in Chapter 2. Usually, metaphors which correspond to the respective topic are chosen for hypertext environments: book, encyclopaedia, the chronological timeline, the biography, the location, the adventure, the machine etc. The rules for use by the learner, the navigation, then depends on the respective metaphor: »leafing« through a book, »wandering« through a landscape.

There is no lack of proposals for the further development of hypertext into hybrid systems. They aim at making navigation mathematical, at a creation of semantic networks [Schnupp (1992), 189], a tutorial accompaniment by expert systems, the integration of knowledge-based generation technologies (192), and access to relational databases. Thus Klar, Schrader et al (1992) suggest computer-linguistic textual analyses in hypertext systems; Ruge and Schwarz (1990) search for linguistic-semantic methods for the relationing of terms; Irler (1992) deals with the employment of Bayesian Belief Nets for generating sentences up to the automatic »generation of hypertext sections on the basis of a formal representation « (115). Klar (1992), who wants to supplement hypertext with expert systems, concludes: »that the formal representations of knowledge in the expert system and the informal presentation in hypertext can complement one another in a useful way« (44). Kibby and Mayes (1993) want to enrich their program *StrathTutor* through the simulation of human memory with attribute and pattern comparisons, and reach the conclusion that parallel computer systems would be more suitable for that purpose. Whether it makes sense to pursue paths of heightening the complexity can hardly be decided at this point, when we know only a few hypertext applications up to now that are comprehensive and have meaningful contents.

Hypertext and Intelligent Systems

Duchastel (1992a) integrates hypertext elements in his ITS system GEO Tutor. Duchastel (1992b) points out the fundamentally different character of ITS and hypermedia systems (199). He wants to develop a hybrid model, with the emphasis on the integration of hypermedia components into an ITS, not the other way round. Does a hybrid model not automatically suppress one of the two diametrically opposed models, namely the more open model which allows more control to the user [Peper (1991)]?

I have already described Duchastel's educational world view which is behind this proposal in the previous chapter on the adaptivity of IT systems. Duchastel pleads for a non-directive tutor who must be able to adapt »intelligently« to the demands of a situation, the student's characteristics, and the currently needed information (200). He outlines a 'learner-centred didactic model' (202). But is adaptation to the learner possible? Is it possible in such a way that non-directive, and nevertheless advisory systems would actually result from it? Is the balance between guidance and explorative freedom feasible? Why does Duchastel take the trouble at all? He speaks of the affective qualities of hypermedia, he calls hypermedia »alluring«, he wants to exploit the motivating effect of hypermedia without giving up educational control over the student. This plan should hardly succeed if one starts out from the hypothesis that the open interactive structure of hypermedia is an important factor for the motivating effect.

Jonassen (1992a) integrates an expert system into a hypertext system, with a completely different objective than Duchastel. Jonassen puts forward the idea of intelligent working aids for the possibility of the integration of expert systems into hypertext. As such an intelligent working aid, he sketches the expert system of a counselling program for instructional design (190), a kind of online help which can query the user for additional information in order to be able to give advice. Jonassen explains the sense of this combination as follows: »Hypertext, if properly designed to reduce navigation, integration and synthesis problems (Jonassen & Grabinger, 1990), provides a very usable interface that can supplant most of the need for natural language. Our working hypothesis is that these capabilities replicate most if not all of the functionality of and [sic!] intelligent tutoring systems« (194). This system may indeed have a functionality similar to ITS, but one can no longer speak of a hypertext if the author's main intention is to reduce navigation. In this manner, the meaning of the hypertext component within the hybrid system is reduced to the role of a comfortable user interface.

The *Physics Tutor* by Jonassen (1992a), a combination of hypertext and expert system which is supposed to have ITS features in addition, reinforces this assessment. The browsing starts out from a network of terms representing the knowledge base. This consists of a semantic network of physics terms and physics concepts which is organized in the manner of the rules of an expert system. The student model controls the declarative, structural, and procedural contents. »The declarative knowledge question is a simple multiple choice paraphrasing of the information presented in the node […]

This information is transferred from the hypertext interface into the expert system which evaluates the information in a backward-chaining rule base and concludes that the learner's understanding of the root concept is inadequate, fuzzy or adequate. This information is fed to the tutorial expert system to generate appropriate instructional interactions« (196). The hypertext component is basically made up of the graphical browser. But the starting point for learning is a multiple choice question, and the student's answer is transferred back to an expert system again.

The implicit risks for the hypertext model on being integrated into IT systems, which have been outlined by way of the examples of Duchastel and Jonassen, are also visible in the following examples:

Moline (1991) presents a combination of *HyperCard*, MacSMARTS, and a knowledge base on Arabic numismatics. The sources of information are databases with pictures (coins from the collection of the British Museum, maps), descriptions of objects, documents (abstracts, references, excerpts), genealogical trees, and timelines of historical dates. The application consists of cards with coins, which the user is supposed to classify. It is complemented by a rule-based expert system to which the user can turn for advice. The expert system guides the user to the solution through a number of questions. The title is misleading: It is no hypertext that has been realized here, but an application that uses hypertext as a comfortable user interface for an expert system that does not have any graphics capability of its own.

Tang, Barden et al (1991) also combine hypertext with an ITS in HITS (HyperCard Intelligent Training System). Authoring and user environment are separated. It is the aim of the authoring environment to save authors the planning of a course, the aim of the learner model is a more efficient adaptation of the HT system to different users and especially authors. Tang, Barden et al do not consider either authors or users competent enough for a free use of the systems. The environment serves a regulating function: The user is offered browsing, guided browsing, and tutorials as possible modes. The philosophy is strongly oriented towards authoring systems.

A somewhat different case is presented by LINCTUS PB by Briggs, Tompsett et al (1993), an advisory program for pharmacists, which guides the users on the hypertext base with the help of rules. LINCTUS PB again combines hypertext with an expert system. The basis are text cards with texts explaining colds. At the bottom of the card, possible links to other cards, which refer to prologue rules, are listed in full text. The expert basis is thus transparent for the user, and the user may still freely move within the hypertext. The links are calculated ad hoc as soon as the user selects one, with an in-built short-term memory preventing the user from going around in circles. LINCTUS PB has a second knowledge-based component, the current patient's card. On this, the pharmacist may enter the characteristics of the respective patient, supported by menus with preformulated terms. The system uses this information in order to limit the search area as soon as the pharmacist goes back from the patient card into the hypertext network. This example makes clear that the hypertext features and navigation have been retained without having to forgo the advantages of the expert system. The expert system retains its own functionality, but has a serving function at the same time by making its knowledge rules available for the calculation of links.

We find a similar combination in the »Medical Center« introduced by N. Anderson (1992), which combines a guided tour through the medical centre with library, computer lab, and laboratory with a patient simulation module, a hypermedia database module, and a meta-database module with clinical cases. The patient module gives access to physician-patient consultations on video. Patient data sheets offer realistic background for a case history. The database contains hints and allows the formulation of hypotheses, which are then weighed by the inference machine. The library can be accessed by way of a browser. The computer lab allows physiological simulations and analyses. In such a hypermedia system, the incorporated elements are all assigned their relative importance and thus come into their own.

So we have basically the following possibilities of combining intelligent systems and hypertext systems:

- Complementing a hypertext with an intelligent tutor in order to adapt links to the learner history or conceptual variables [e.g. Duchastel (1992a); Hammond (1989), 176]
- Integration of an expert system for the ad hoc calculation of links [e.g. Diaper/Rada (1991); Rada (1991); Kibby/Mayes (1993); s.a. Gloor (1990), 260ff.]
- Integration of an expert system for the selection of data from a database [e.g. Littleford (1991)]
- Integration of an expert system in order to support hypothesis formation and testing in the hypertext [Mayes (1992a), 13]
- Complementing an expert system with a hypertext with the aim of adding flexible explanatory components to the expert system [Gloor (1990), 260ff.]
- Expert systems with a hypertext interface as »system glue« [Smith/Wilson (1993)].

These possibilities do not, however, say anything about in how far the respective systems emerge intact from this combination, as we have seen with the examples of Duchastel and Jonassen. In the installation of tutorial advice functions with student models, either the free use of the hypertext system is limited in an intolerable manner, or the tutorial component is restricted to the role of a help dialogue [Pereira/Oliveira et al (1992)]. In combining expert systems and hypertext systems, either the expert system assumes a serving role, or the hypertext system is reduced to the function of a nice user interface [Lowyck/Elen (1992), 142], because »there is little empirical evidence for the utility of expert systems, based as they are on an extremely restricted understanding of human knowledge utilisation and decision making« [McKnight/Dillon et al (1991), 137]. Dillon (1991) himself postulates a kind of cognitive suprastructure that guides the reader in reading a text. His attempt to transform research literature into hypertext ends in retreat, however: the standard structure of scientific articles is imitated, since this corresponds more closely to the readers' expectations.

Hypertext programs allow the learner to wander through the information material on arbitrary, associatively selected paths, but also on logical, factually and thematically founded ones, or those guided by hypotheses. If one wants to reflect on hypertext as a didactic-methodical medium, it is important to state that the structure of the given material cannot be changed without calling the genre hypertext itself into question. I cannot simply »work over« a hypertext system with concepts from instructional design without giving up the structure of hypertext as such. As a specialist in teaching methods, I can only make hypertext »pedagogic« by enriching the given material through pedagogic-methodical advice from teachers (links, comments, references, hints, questions, tasks, testing, evaluation), or through annotations by the learners.

Cognitive Plausibility of Hypertext

An evaluation of the learning processes in working with hypertext is made rather difficult by the complex structure of hypertext, and the next to unlimited freedom it allows the learner, but also by the advance burden put on the evaluation by qualitatively high and complex hypotheses dealing with the topic of hypertext and learning. Ambrose (1991) refers to these unproven educational theses, or, as I would put it, »educational myths«, when he says: »Research examining the relationships between hypermedia and learning has an unfinished quality« (52).

There has been no thorough examination up to now of whether hypertext has advantages for the motivation of learners. Many authors seem to agree with such a hypothesis, however. Whether hypertext also has cognitive advantages is even less clear. A thorough overview of learning with hypertext with carefully judged conclusions and generalizations has been presented by Kuhlen (1991, 180ff.). Kuhlen sees hypertext as a medium that potentially fosters learning, because of its flexibility in accessing knowledge and its suitability for active learning:

»The potential surely lies mostly in the flexibility of accessing knowledge. Learning situations are very much individualized situations, so that educational materials should be able to react to different levels of ability, experience, and understanding«.

»Furthermore, learning success is obviously furthered if learners develop individual initiative, i.e. if they can explore teaching materials, as is possible in hypertext with a good design, instead of just having to follow preset paths, as was the rule in previous forms of programmed instruction«.

Non-linear Reasoning

Beeman, Anderson et al (1987) have proposed the hypothesis in their evaluation of Intermedia that hypertext structures foster the development of non-linear reasoning in students. They do not explain, however, what they understand by 'non-lineal' or 'non-linear' reasoning, or »multi-causal reasoning«. Kuhlen (1991) speaks of 'pluralistic, relativistic, critical' reasoning (198). I think that what is meant here is rather a reference to qualitative-cognitive concepts like formal, relativistic reasoning in the sense of Piaget or Kohlberg than a reference to connectionist models. Beeman, Anderson et al are concerned with an educational fostering of learning in the first place. In a way, the thesis implies an analogization of cognitive structures and hypertext structures, another correspondence hypothesis, which does not however have any relationship to the Physical Symbol System hypothesis which I have discussed in the chapter on instructional design.

Beeman, Anderson et al comment that the learning effect was considerably higher with the persons who had participated in the development of the materials than with the students – a demonstration of the pedagogic maxim »learning by doing«. They surmise: »Apparently one succeeded in finding teachers at 'Brown University' who had already formulated the development of perspectivist, non-lineal reasoning as learning objective for their courses without having achieved that objective on the basis of conventional texts« (199). After looking through the evaluation data, Kuhlen reaches the conclusion that data pointing towards the dichotomous hypothesis »are not easily interpreted« (203). Even if one grants the result a good deal of persuasiveness, the question remains whether the fostering of non-linear reasoning can really be ascribed to the hypertext system, or whether it is due to other factors of the experiment that were not checked, e.g. to the demanding contents, the above-mentioned teachers convinced of their cause, or the institutional context, because the Intermedia-experiments were mainly conducted in English Literature and History, after all – other than most of the evaluation studies discussed in this book.

Hawthorne Effect

Duffy and Knuth (1990) are perhaps right in assuming that the fostering of non-linear reasoning »rests primarily in the pedagogy of the professor rather than in the database«. Beeman et al's observation that the developers showed the greatest learning progress in the course of the project seems to me to indicate this very point. In this spirit, McKnight, Dillon et al (1991) in their criticism of the study also come to the conclusion that the positive results could just as well be put down to the Hawthorne effect (113): »At first sight, the effects of introducing hypertext seem to have been positive […] However, they also report an unexpected finding which suggests that improvements may not have been attributable to the introduction of hypertext per se but rather to factors related to its introduction« [McKnight/Dillon et al (1991), 112ff.].

Connectionism and Hypertext

In contrast to Beeman, Anderson et al, Kuhlen (1991) describes the relation between hypertext and reasoning as a correspondence of networked structures: »Hypertext seems to be cognitively plausible under the assumption that knowledge, whose acquisition is the general objective of learning, is organized in the human brain in networked, topological, non-linear structures« (182). This hypothesis, called cognitive plausibility, is rather closer to a correspondence hypothesis than that of Beeman, Anderson et al. The plausibility hypothesis determines the research of many authors, even if it is hardly anywhere explicitly formulated. It assumes a definite character in Jonassen (1986), who calls hypertexts 'semantic webs', and learning »web-learning«. With this metaphor, Jonassen wants to suggest a correspondence of the represented knowledge's web structure with the semantic web structure of human learning, aiming to find knowledge gaps and clear up inconsistencies. Hypertext imitates the associative network of human memory, Jonassen and Wang (1992) claim, thus not only proposing the correspondence of hypertext and memory, but also a hardware hypothesis about the brain that does not hold up under recent studies of brain research [e.g. Roth (1994) and Rusch, Schmidt et al (1996)]. The hypothesis of the cognitive plausibility of hypertext assumes that the structural similarity of text and reasoning is responsible for cognitive learning success. It is thus a variant of the correspondence hypothesis of knowledge and memory, and the idea that knowledge can be stored in memory as in networks. The thesis shows some similarities to connectionist models [Rumelhart/McClelland 1986; McClelland/Rumelhart 1986], which conceive learning as self-modified networks, and with adaptive neuronal networks for tasks like e.g. visual recognition, speech recognition, recognition of handwriting, reading, and the successful processing of other sensory input. Connectionist models are structurally close to self-organizing biological systems [Varela (1990)]. Neuronal networks only work on subsymbolic levels up to now, however. This is actually to the advantage of connectionism, because it can thus do without the representation concept of the Physical Symbol Systems Hypothesis, without the hypothesis of the mirroring of cognition.[24] But this also makes expansion, imagined by Varela as an inclusion relationship between connectionism and symbol processing, difficult and puts it a long way off. A connection of hypertext systems to semantic networks can therefore only be meant metaphorically. McKnight, Dillon et al (1991) are much less interested in the analogy to connectionism in Jonassen's statement than in Jonassen's underlying motive, which they criticize as 'teacher-controlled strategy': »Assuming not only that the structure of both the learner's current knowledge and the topic can be represented but also that methods exist for making meaningful comparisons between such structures, the aim is 'to fill the gaps'« (117). Whalley (1989/90) [cited in Jonassen/Mandl (1990)] utters similar criticism of a premature analogization of hypertext and reasoning structures.

Theory of Cognitive Flexibility

Spiro and Jehng (1990) argue on the basis of their cognitive flexibility theory that hypertext systems are particularly suited to working and learning in »ill-structured domains«. Their own experimental example is a program with video access about the film Citizen Kane by Orson Welles. The cognitive psychological conceptualization of the subject matter leads them to the hypothesis that hypertext systems are »best suited for advanced learning, for transfer/application learning goals requiring cognitive flexibility, in complex and ill-structured domains – rather than introductory learning, for memory tests, in simpler domains« (167). Since they assume that »learning of complex content material in ill-structured domains requires multiple representations – multiple explanations, multiple analogies, multiple dimensions of analysis« (168), hypertext systems seem to them particularly suited to this form of learning, because hypertext components are characterized by the fact that they may enter into varied connections and relationships with each other at any time. Spiro, Coulson et al (1988) also restrict learning with hypertext to advanced knowledge acquisition, using the medical text Cardioworld Explorer as their example.

Why do Spiro and Jehng designate whole fields of knowledge as »ill-structured«? The term is obviously chosen from the perspective of a scientist who really wants to do instructional design from a complete task analysis, or a fully covered domain. Simon and

24. Connectionism is a hypothesis about functioning neuronal learning systems, but not necessarily a simulation of human learning, at least in Lakoff [s. the interview with Lakoff in the volume of Baumgartner and Payr (1995)].

Hayes (1976) go into this in extensive detail. Just compare the use of this term in Newell (1973), who observes that the employment of artificial intelligence methods has remained restricted to problems that are well-structured: »For the sake of illustration, what might we take as an ill-structured task? Deciding on a career. Discovering a new scientific theory. Evaluating a new ballet. Planning what to do with a free day. Painting a picture. Making conversation with a just reencountered long time acquaintance. Designing a new house. Making a new invention. Finding a way out of Viet Nam. Thinking up a critical experiment to test a scientific hypothesis. Making a silk purse from a sow's ear. Generating this list« (55). If one looks at the list, one notices first of all that all these examples are practical situations of decision-making, generating new ideas, and problem-solving in open situations. Designating such problems as ill-structured may be legitimate, because they deal with practical issues and decisions, i.e. with open situations whose parameters or »constraints« are not yet known. This is however completely different from characterizing entire fields of science as ill-structured.

Spiro and Jehng use the term to characterize features of fields of knowledge. They elevate the term to the status of object characterization. It seems that all hermeneutic fields of knowledge are »ill-structured« to them (in analogy to the term 'ill-defined' used in methodology?). I do not think that this is still legitimate. The important characteristic of hermeneutic knowledge is not that it is open, but that it can only be opened up by way of interpretation, with the interpreter becoming part of that knowledge. Thus hermeneutic knowledge is not unstructured, but differently structured, it can only be opened up in a self-reflective and recursive manner. Spiro's argument, turned into a positive statement, would have to be that hypertext might be suitable as a representational medium for hermeneutic sciences. But one does not have to call in cognition psychological quasi-concepts (cognitive flexibility, ill-structured domains) in order to explain that hypertext systems are best suited to hermeneutic fields of knowledge and definitely better suited to them than CBT. One might even claim that hypertext systems are particularly suited to the learning of higher taxonomic levels of learning objectives, whereas CBT is rather suited to learning in the lower areas of the learning objectives taxonomy. The view seems to prevail, at any rate, that hypertext systems are an ideal medium for discovery learning [s. McAleese (1993b), 19].

What forms relational reasoning can take in students who work over a hypertext as authors becomes clear in a study by Brown and Chignell (1993). Students had the opportunity here to type links with the help of a palette in which they could assign meanings to the individual icons. The result was not at all a cognitive penetration of the subject matter: »subjects not only choose different link meaning, but also different kinds of semantic structures in organizing information« (41). The test persons not only reported that they had several times changed their strategy of placing anchors, but even that they had sometimes followed more than one strategy at a time.

The plausibility hypothesis or the related thesis of the mirroring of reasoning in hypertext seem doubtful. What cannot be doubted in my opinion, however, is that hypertext offers the learner a complex learning environment that enables him to behave naturally, with »natural« meaning two things here:

- First, the learning materials in a complex hypertext system represent an environment which the student also encounters elsewhere (if he/she does proper research!), in the library, on his desk, etc., an environment consisting of many books, pictures, primary literature, secondary literature, bibliographies, and other material, connected only by loose threads. Illustrative examples for such complex environments are the applications »English Literature from 1700 to the present day« and »The Biology of Plant Cells« developed with the hypertext system Intermedia, which are described at length in Yankelovich, Haan et al (1988).
- Second, the student can also behave in this complex environment in the way he is used to do, that is he can e.g. employ his usual, habitual learning strategies, either learning by heart or formulating hypotheses, browse wildly or conduct a deliberate search, study the material in linear sequence, or search for connections, »cram« with extrinsic motivation, or identify with essential questions and problems with intrinsic motivation. Hypertext is open and accessible to and for all kinds of individual styles and habits of learning.

With this open characteristic, the program type hypertext emerges from the behaviourist paradigm of learning and the »frame-based« learning programs, and comes close to ideas of a natural process of learning, as they have been formulated in the epistemological theory of cognition [s.a. Lave 1988, 92 and 173]. Working with hypertext becomes similar to the process that has been called »reading« for centuries, and which is known as an interpretational, hermeneutic process. It is in this spirit that Collins and Brown (1988) formulate their idea of the computer as a tool for learning through reflection.

This discussion points us towards an obvious deficit in the psychology of learning: Why is there no theory of learning on the basis of a theory of understanding? Rogers' humanist psychology might be most easily suited, but it has never developed a theory of learning. One exception – in the field of learning with computers – is, at least in parts, constructivism, e.g. the projects of Brown and Palincsar (1989) and the basic design of Winograd and Flores (1987), but unfortunately – as has already been remarked – the communication theory and hermeneutic dimensions of learning and understanding have not received much attention yet in constructivist learning environments.

Evaluation of Hypertext (Navigation)

After a thorough overview of studies on learning with hypertext (180ff.), Kuhlen (1991) comes to the cautious conclusion: »The results of studies up to now suggest that the non-linear features of hypertext may further learning success in complex situations, especially when there is a certain amount of prior knowledge and high motivation can be assumed. [...] But success and failure depend on so many factors – surely also on the current technological and methodological state of existing systems – that generalizing statements, e.g. with regard to the cognitive plausibility of non-linear hypertext structures, are still not appropriate« (211).

A comparison of teaching methods of hypertext learning with other forms of learning (lecture, literature, learning group) was carried out in the evaluation of the business science hypertext program HERMES by Schoop (1992). The study does not yield very positive results, however: The students rated the program more highly than the lecture, but the test persons' opinions with regard to the comparison with literature were divided, and the program came off worse than the learning group (163). In the final paper, the students who had been working with HERMES showed slightly better results than the control group, but the result of a paper with free text answers was disappointing to the authors of the study: the students merely reproduced the HERMES texts (164). The authors see an explanation in the observation that the students did not make use of the hypertext system's freedom, they »were glued to the path« (163).

It is conceivable that this behaviour is the result of a not yet fully realized hypertext structure, a possible interdependence of navigation concept and predetermined studying behaviour. A fact in favour of this argument is that HERMES has a relatively low degree of freedom and not enough elements of discovery learning in my opinion. How can one then expect different studying behaviour? It is also conceivable, however, that in the case of the business science students we are dealing with a somewhat one-sided sample with regard to motivation and learning strategies. In such a case one would have to allow more time to the students to practise the learning behaviour expected of them. Hasebrook (1995) supposes an interaction of form of examination and learning behaviour. Many possibilities of navigation had not been used in his opinion, »because the students wanted to stick to tried and tested methods of preparing for an examination and were inexperienced in working with hypertext« (101). These factors were not checked in the study. But they can provide us with a hint that multimedia as such, without a consideration or change of the general conditions under which multimedia is employed, will not necessarily bring about the expected success.

Similar reservations apply to the experiment of Hasselerharm and Leemkuil (1990), who compare different control strategies of learning programs (program control, student control, and adaptive program control), but do not find any significant differences in posttesting (77). Perhaps the authors would have got different results if they had left the choice of method to the students, so that they could have found the one best suited to their style of learning.

Such non-results point to the general dilemma of controlled experiment set-ups in social science fields (s. the chapter on evaluation). The results of comparative evaluations in the field of teaching science and methodology depend on the realized environment, especially on the learning prerequisites of the students and the learning objectives implied in the posttesting. It is impossible to optimize two learning methods in such a way that their respective features appear in a positive light, and to measure them with posttests that are fair to both methods and still test the same learning objectives. I make the claim that the exact opposite result could have been achieved with another program (i.e. other learning offers, learning structures, learning objectives, and tests).

A study whose aim was to clear up exactly such dependencies of learning prerequisites and learning behaviour is the one by Mandl, Schnotz et al (1992). The authors asked the following questions:

- »Do learning processes and learning results differ in presenting a content by means of hypertext versus a simultaneous graphical text presentation?

- Are these effects of the type of text presentation on learning processes and learning results different according to specific processing orientations?
- Are these effects on learning processes and learning results different for learners with different learning prerequisites?« (71ff.)

Learning Prerequisites

No differences in understanding were observed in the test persons; the only significant differences were between learning prerequisites and understanding, and intelligence and understanding: »the use of hypertext did not result in an improved retention of the learning material. If one takes the subjects' learning prerequisites into consideration, differences between the types of presentation appeared. In learning with hypertext, subjects with higher learning prerequisites (higher prior knowledge, higher intelligence) reached a higher number of propositions and a higher number of transitions than in learning with the simultaneous graphical text presentation […] The results of this study show that learning with hypertext is not necessarily more advantageous than learning with simultaneous graphical text presentation« (74ff.).

Again, this does not say anything about the characteristics of the medium hypertext as such. But the hypothesis that general learning ability interacts with the demands of hypertext seems to be confirmed by the study. The pedagogic conclusion one might draw from this would come down to a fitting of learning prerequisites (intelligence, prior knowledge, styles of learning) and learning methods. The authors do not find any significant differences between the two methods as such. Could this be due to the fact that the example was badly chosen, was too small in dimension, or was tested with far too many test items? The only secure result, that learning prerequisites interact with the method, corresponds to Espéret's (1992) finding, at any rate, that test persons with higher prior knowledge make more effective selections in hypertexts (116).

Interactivity

Silva (1992) calls interactivity the best that hypermedia has to offer: »We believe to be fundamentally important to find out to what extent this interactivity can and may play a relevant role in learning processes« (145). His hypothesis is, however, that the success of hypermedia-supported learning depends on two factors, the learner's degree of freedom in exploring the data, and »the help to the location in the hyperspace, interactive or not, supplied to the users« (150). Silva has pursued these hypotheses in an experiment with the virtual museum »Palácio da Bolsa«. The model of the museum is a museum from Oporto simulated in *HyperCard* with a floor plan and views of the rooms. The navigation was evaluated. Four groups (40 students) were formed: sequential exploration, free exploration without a map, free exploration with a map, and free exploration with an interactive map. The last group achieved the best results, the group 'free without a map' achieved the lowest results. Weaker students profited from the sequential method, better students rather profited from free navigation even without a map, but even more with an interactive map. Silva's conclusion: »The data analysis suggests that the degree of information holding in the learning process, in hypermedia teaching systems, seems to be correlated to the introduction of interactive help to data exploration« (155).

Patterns in the interactive behaviour of students while learning with a hypermedia system on cell biology have been studied by Hutchings, Hall et al (1993). Their model basically consists of hypertext with graphical maps. The students' tasks varied from note-taking to answering a multiple choice questionnaire. In their evaluation, they reach the conclusion that »note-takers made considerably more use of hypertext links than those answering multiple choice questions […] However, note-takers viewed a smaller number of different nodes than the multiple choice questions answerers« (310). This should not come as a surprise: A reflective dealing with hypertext, as is required for note-taking, should automatically lead to a more thorough processing of fewer nodes, while the multiple choice test enforces a working with hypertext that is geared towards memorizing. This seems to be a clear case of the testing method's affecting the style of learning, a methodical problem that is often overlooked in evaluation studies.

Trumbull, Gay et al (1992) use a hypermedia application on cultural entomology with three different built-in navigation instruments to examine which of the navigation tools were chosen by the students. The students were afterwards classified into four groups according to the navigation data: *Browse*, *Index*, *Guide*, and *Mixed*. In interviews, they ascertained that most of the students were indeed aware of their chosen navigation strategy's dominant mode. On the basis of this classification, the students' navigation was then studied: The browsers visited most events, had the impression that they had viewed all relevant information, and spent most time with the program. The guide students were likewise content with the information they had viewed, although they had seen a little less. The mixed group had viewed about the same amount, but was unsure whether it had found all essential information. Positive arguments for graphical browsers and other visual means of representation are offered by the study of Campagnoni and Ehrlich (1989). According to them, better visualization supports the hypertext users in their concept-formation [s.a. Conklin/Begeman (1988)].

Janda (1992) reports 'sobering insights' from an experiment with an interactive laser disc system in political sciences. Parallel to a course of lectures on the policy of the American government, he arbitrarily assigned the students to three different tutorial groups: traditional seminar, tutorial group plus computer program, tutorial group plus laser disc. The laser disc contained films on the Watergate scandal, civil rights, Vietnam, and other topics, and was accessed by a kiosk developed with *HyperCard*. The subjective opinions of the students on the multimedia program were enthusiastic. But the students in the traditional seminar group did slightly better in the final test. It becomes clear from the interviews that the students saw the multimedia program as a valuable addition for themselves, but had not recognized the contribution that the interactive video was supposed to make to the final examination. The conclusion that Janda draws from this can be wholeheartedly endorsed: »Multimedia produces other forms of learning that are not measured by performance in the course nor by expressions of interest, knowledge, or future course plans« (350). The multimedia advantage apparently lies in other areas than with the learning objectives demanded by the traditional curriculum. What we have here is a repercussion of the known examination system on the students' attitude. They did not recognize the multimedia program's relevance because they knew they had to write a test in the end which counted for 40% of the final mark.

Evaluators would like to know what mental structures occur in learners. In the experiment of Gray (1990) one tried to reconstruct the user's mental models of the text, by asking the users to represent the information space in the form of a diagram. Initially, the test persons chose linear structures for this task; with growing experience the diagrams grew less linear as well. The result of the study seems to indicate that a medium like hypertext takes some time for its users to get used to and be able to exploit its advantages.

Searching Behaviour in Learners

Another interesting dimension in the studies on learning behaviour with hypertexts is the readers' searching behaviour. Some studies treat this topic as the difference between searching and browsing. McAleese (1989) views browsing as navigation with tools and intentional objectives; Allinson (1992b) sees browsing as »exploratory mode« [Marchionini/Shneiderman (1988); Shneiderman (1989)]. In a museum application, the search for particular information is carried out by way of the index, while viewing selections mostly occur in browsing and are made by way of embedded menus. Campagnoni and Ehrlich (1989) think that the use of the index depends on the type of question; Rada and Murphy (1992) get the impression that multiple outlines were not helpful to users; browsing worked better in books, searching better in hypertext [s.a. Qiu (1993a)]. Horney (1993) examines the hypertext navigation patterns of seven users in case studies, and identifies five patterns. Jones (1989) studied the effect that embedded menus and index as browsing and searching procedures have on incidental learning[25]. She does not find significant differences in the overall performance and concludes by herself that the results depend on the type of database and the set task. In her study, she also finds various reading strategies and searching procedures which were not recorded by the experiment's setup itself. McKnight, Dillon et al (1991) suppose that the tasks were not suited to this (120). Does browsing have instructional effects? Sadler (1993) conducts an experiment with a control group using the *Glasgow Stack* as example: The one group has no particular task (free browsing), the other group is assigned a specific task. The first group proves to be superior. They view this result as evidence for the power of incidental learning. Beasley and Vila (1992) analysed the students' working with hypertext according to linearity and non-linearity, and in relation to learning ability, which was measured with the ACT test. Although the differences were small, they thought themselves able to state that weaker students used the multimedia application in a less linear and explorative way than medium learners or good students. Now, this observation does not fit any of the possible hypotheses.

Yacci (1994) criticizes most navigation studies for only recording surface navigation patterns and not the actual strategies and objectives of the test persons. He tried to analyse the mental models of hypertext users by way of a factor analysis of their cognitive learning patterns. User behaviour was examined with regard to quality, and coded in the form of learning events. 16 different learning events were found, which through a factor analysis were reduced to eight factors. This solution cannot be interpreted. In my opinion, the reduction of factors and thus the analysis' information density is not high enough, because only two to three variables load with each factor.

Chimera and Shneiderman (1994) examined three different user interfaces for tables of contents. The students took different amounts of time for the same task with the three interfaces, an average 63

25. On intentional versus incidental learning or informal learning cf. Bock/Kirberg et al (1992); Strittmatter/Dörr et al (1988).

seconds for the table of contents with scrollbars like those in a word processor, 41 seconds for the expanding/contracting one as in an Outliner program, and 42 seconds for the system with several layers. Thus the two latter forms allowed the user to handle the contents more quickly.

One may pursue these studies ad infinitum: Qiu (1994) is interested in whether the search task has an influence on the path patterns in hypertext (it does not!). He registers the frequency of node visitations. Qiu (1993b) describes the users' search patterns with a Markov model. Again – as with the evaluation of hypertext systems – we have an atomization of the problems studied, the nitpicker syndrome. And every study leaves us just where we were before, with a demand for further studies: next time, one should differentiate according to the quality of nodes, the scope of the tested hypertexts, the size of the sample, the inner differentiation of the sample, etc.

Studies on the probabilistic frequency of user actions also do not yield anything better than the distinction of searching vs. browsing [Aigrain/Longueville (1992)]. One can see to what absurdities this can lead if one reads what computer expense and effort are necessary for the generation of meaningless columns of figures: »But our graph has 13561 vertices and is much larger than those of most other systems […] The computation of the distance matrix takes about a month on a SUN4™ workstation« (525). What kind of studies are these that yield : »This is no real surprise to us« (525), and »as we had foreseen« (526) – even the result presented as interesting is trivial: The efficiency of searching for pictures depends on factors like type of picture, quality of description, the computing method for links, the topology of links, and the user interface. We knew that before.

The other side of the coin is marked by the statement of van den Berg and Watt (1991): »The number of dramatic claims that have been made for the value and user acceptance of different types of hypertext easily outstrip the number of empirical studies that support such claims«. They conduct an experiment with the hypertext document LAST (Level of Abstraction Text, for introduction into statistics and the statistic evaluation of hypotheses): in three consecutive semesters, three different methods were tried: competition to a course of lectures, complementing the course of lectures, and replacement for the course of lectures. Their conclusion is rather sobering: »Objectively the academic performance of LAST users was no different from those attending classroom lectures. Their subjective evaluation was somewhat negative. Although positive about

LAST technology, they indicated they would prefer to use it as supplement to lectures and books« (119). The critical opinions of the users were varied, but superficial. A third of the criticism was concerned with the speed of the system (121). The variation in criticism of the system's shortcomings is interesting: more than three quarters of the test persons in the Competitive condition complained about the lack of a sketch or help, but only 6% of the test persons in the Replacement condition did the same: »Perhaps the students in the Competitive condition felt deprived of the implicit and explicit guidance their counterparts in the control group were receiving in lectures. The students in the Replacement condition could not feel such deprivation« (121). The test persons' judgements are thus clearly dependent on the condition, the respective environment of the experiment. For the purposes of experiment methods, one can only assess them as artefacts.

Glowalla and Hasebrook (1995) and Dillon and McKnight (1995) formulate demands on the evaluation of hypertext systems and the consequences resulting from those evaluations on the design of these systems. Evaluation is determined by the search for the optimal system, but no hypertext system will ever achieve universal usability. Among the factors that have an influence on usability are the individual variance of users, the variation of tasks, and the functional difference between using a hypertext and using a book [Nielsen (1989)]. More on usability research will be found in Nielsen (1990b). Grice and Ridgway (1993) suppose, however, that the known usability criteria will not suffice for the evaluation of hypermedia.

Reading Behaviour in Books and in Hypertext

Comparing reading behaviour in a hypertext with that in a traditional book basically pursues similar intentions as the cognitive plausibility hypothesis. The question is whether the reading behaviour corresponds to the structure of the text, and whether that correspondence has cognitive effects. Such a comparison between a conventional text on statistics and a hypertext has been carried out by Egan, Remde et al (1989a): »students using SuperBook answered more search questions correctly, wrote higher quality 'open-book' essays, and recalled certain incidental information better than students using conventional text« (205) [s.a. Egan/Remde et al (1989b)]. The hypertext readers relied more heavily on the table of contents, read the same amount, but solved the problems in less time.

McKnight, Dillon et al (1991) criticize the method: »a closer look at the experiment is revealing. For example, with respect to the search tasks, the questions posed were varied so that their wording mentioned terms contained in the body of the text, in the headings, in both of these or neither« (59). What was being tested was the computer's searching abilities, not those of the students. McKnight, Dillon et al designate the evaluation as »biased against the paper condition« (60). They point out that Egan, Remde et al had carried out an earlier study which had not yielded any difference, and that they had then improved their hypertext version in such a way as to ensure the emergence of differences. Cautiously, they call this kind of research strategy a classic example of iterative, user-centred design. Faced with conflicting evidence on the subject, they conclude that each of the two media has its own specific advantages and drawbacks, »e.g., hypertext is better than paper when locating specific information that is contained within the body of text but seems to offer no clear advantage when readers have only an approximate idea of what they are looking for« (60ff). Among the factors not controlled in this study are the students' motivation, the novelty effect of subject and medium, alternative structures of textual organisation, alternative forms of tasks etc., which, after all, might constitute the medium's attractiveness and learning efficiency.

McKnight, Dillon et al (1991) give a thorough overview of comparisons of book and hypertext. They also report on a study by Simpson and McKnight (1990), in which the test persons had to answer 10 information questions first, and then were asked to draw a diagram of the text structure: »Results showed that readers using a hierarchical contents list navigated through the text more efficiently and produced more accurate maps of its structure than readers using an alphabetic index. The current position indicator and additional typographic cues were of limited utility« (62ff). The results of such comparisons depend on an optimal design of the methods compared. A badly designed hypertext will fare badly with users.

Thus Krauss, Middendorf et al (1991) reach conclusions in comparing hard copy version and online documentation which are easily explained by the bad design of the online documentation: users of the screen version are slower because they have to keep moving windows all the time, they get lost in the texts because there was no proper backtracking method.

In Gordon, Gustavel et al (1988), readers of the hypertext version of texts do less well than readers of the linear version by 1.000 words; subjective preference is in favour of linear texts as well; the proportion is about the same for technical texts. Several questions immediately come to mind, such as: Were the texts too short? Are the users too inexperienced with regard to hypertexts? [Nielsen (1990), 239]

Happ and Stanners (1991) compare hypertext with embedded vs. iconic anchors with reading hard copies. The readers of both hypertext versions showed advantages over the readers of the book version.

Mynatt, Leventhal et al (1992) compare the electronic version of the *HyperHolmes Sherlock Holmes Encyclopedia* with the book version. The performance of both test groups is about the same, response behaviour differs, advantages and disadvantages are evenly spread over both groups: hypertext users give better answers to embedded questions, book readers do better with questions whose answers could be found in maps. Instone, Teasley et al (1993) chose a new design for the *HyperHolmes Sherlock Holmes Encyclopedia*, which improved the correctness and swiftness of the users' answers. They installed fixed instead of tiled windows, and a simplified search instrument.

Landow (1990) launches a frontal attack against comparisons of book and hypertext. To him, hypertext is not an imitation book, but has new qualities. He criticizes that the studies on navigation are carried out on the basis of much too small systems. His judgement carries some weight, Landow is after all one of the few hypertext experts, who has a lot of experience in the use of big systems in actual teaching, because he has often employed Intermedia in his seminars on English Literary History [Landow (1989b); Landow (1992b)]. His experience seems to demonstrate conclusively that users are not faced with serious problems by navigation in hypertext systems. Landow's objections are worth thinking over, even if they are not backed by empirical studies. A university teacher cannot afford using a medium to teach hundreds of students for years and years if the medium actually is no good. We should therefore ask what the difference between experimental studies and actual practical use might be. Some aspects immediately come to mind when thinking of Intermedia: It is one of the best, most elegant systems, and it comprises large collections of texts and images. The texts were not created for experimental versions, but for actual teaching. And students can work actively with the medium themselves. Finally, and I have already pointed this out in the previous chapter, the students are taught by particularly motivated university teachers, who support the idea wholeheartedly. Landow's practical experience points emphatically to the role of experienced hypertext users for the success of hypertext systems. Navigation problems appear quite different to experienced users than to inexperienced users, with whom most hypertext developers seem to reckon. Rouet's (1990) study also points in this direction. Rouet expressly examines interactive dealing with texts by way of inexperienced users. Most studies either do not indicate the test persons' level of experience, or the studies choose inexperienced users in the hope of being able to study »naive« navigation behaviour. This is however not really necessary. Why not assume that future users of hypertexts will have the opportunity of being introduced to this medium as a matter of course, and that hypertexts are designed for repeated use. Then we could keep the adaptation effects out of the studies and would have to conduct experiments expressly with experienced users.

Another objective of some hypertext studies is to be able to describe navigation and reading behaviour in hypertext systems more precisely. For that reason, McKnight, Dillon et al (1991) establish an analogy of reading to navigation in a physical environment: In a complex physical environment, a schematic representation or model of that environment is needed for navigation, a frame of reference that on its lowest level registers landmarks, from which a cognitive map is built, which on a second level contains paths or routes, and records overall knowledge on the third level (69). Following up this analogy, Dillon and McKnight (1990) draw on psychological research on mental models in readers when using road maps [Dillon/McKnight et al (1990); Canter/Powell et al (1986)], which seem to point toward links being more helpful for non-experts.

A similar approach by way of mental models is taken by Dillon (1991c), who studies the placing of paragraphs within a superstructure. Horney (1993) reconstructs the navigation patterns of seven authors/readers by way of the example of an application written in *EntryWay*, and observes five patterns: linear, linear with excursions, star, star with excursions, and chaos.

An experiment with a hypertext document on the city of York with 39 different screens and five different conditions was conducted by Hammond and Allinson (1989). In explorative mode, the prepared tour was frequented more often, in directive mode, the index was consulted more frequently. Test persons visiting less screens retained more of the information contained in them and did better with questions related to those screens in post-testing, while test persons visiting many screens retained less data: »Users of bare hypertext thought they saw the most materials, but in fact they saw the least«. Hammond's and Allinson's conclusion echoes the age-old wisdom born from experience: »less is more«. Hammond has already explored this conclusion in other articles, e.g. Hammond (1992): »strict hypertext-based systems can be ineffective if learners merely ramble through the knowledge base in an unmotivated and haphazard fashion«. I suppose, however, that the problem was too small to generate real differences.

By analysing the log files for the *Hitch Hiker's Guide*, Allinson (1992a) tries to get closer to the learning behaviour of two groups, who were assigned tasks for explorative learning on the one, and directive tasks on the other hand. The use of various tools, for navigation and tours on the one hand, and index and searching on the other hand, differed for the two kinds of task. Allinson summarizes the results of the study as follows:

- »Most users employ most of the facilities
- Metaphor is understood and helps in using the system

- use of the facilities is a function of task, student and time on the system
- Facilities are used appropriately to suit the task in hand
- Increased efficiency when appropriate tools are available« (293).

Efficient use of hypertext systems, and this is no surprise, clearly depends on interaction with the users' learning styles and strategies. Meyrowitz (1986) observed that users of the Intermedia system who used the system passively rather than actively showed less learning progress. Efficiency apparently also depends on the kind of support the user interface offers for different learning styles. A hypertext in the raw generally seems to be suited to only very few readers. Hammond (1992) warns against seeing hypertext as an educational panacea: »The mistake, perhaps, is to think of hypertext as a closed approach to CBL: it provides one set of tools from the educational technologist's toolbox, to be used judiciously alongside others«. Hammond (1992) not only reacts sceptically to the euphoria that many authors of hypertext applications exhibit towards their systems. He clearly puts the software as such into perspective when he reacts fearfully to the openness of hypertext and belatedly wants to make it 'user-safe' through artificial limitations. Hammond's reflections are alien to hypertext: he starts out from specific learning tasks, provided by the teacher, in connection with a specific predetermined learning objective area, as in the instructional design approach (»learning is task-dependent«). In order to realize this task-dependence, he must resort to the system patterns and 'safety' of learner-controlling systems. I have already gone into this in the chapter on learner control [vs program control]: the alleged motive for so much control is the claim that the user might get lost or lose his bearings. The consequence of this strategy is this: Hammond reduces hypertext to a Guided Tour. It is especially deplorable that such reflections have been given space in a reader with contributions of cognitivists and constructivists on cognitive tools.

Cooperative Learning

Hypertext systems seem to be especially suited for cooperative learning. This is hardly surprising, because hypertext systems largely deal with history of thought topics that must be treated discursively. Cooperative learning research experiments with various forms, »shared learning«, learning in pairs, and other cooperative forms of learning. Cooperative learning is also studied in other multimedia and hypermedia environments. With this in mind, Yoder, Akscyn et al (1989) call KMS a »shared-database hypermedia system«, which they want to employ for cooperative purposes. I will not undertake a differentiation by environment in this section, but rather deal with the aspect of cooperative learning in general. Most studies on cooperative learning choose methods of classroom observation and interviews for an evaluation. Their results can therefore only be reported here in an inadequate summary.

The cooperative learning supporters' hypothesis is that the method of cooperative learning not only determines the quantity of interaction but especially its quality. Dalton (1990) for example turns his attention to criteria like the equality of relations, the reciprocity of relations, and a more highly developed help behaviour. In many cases, cooperative learning goes far beyond what would be required by the immediate work with a computer program. Some learning situations are arranged in such a way that the game in the program turns into role play of the cooperators. Rada, Acquah et al (1993) report on the employment of the MUCH program for cooperative learning at the University of Liverpool [s.a. Rada (1991)]. They integrate a tool into MUCH for this purpose which allows a reciprocal evaluation of the students' contributions, and role play in a simulated hospital. But is it enough to state that cooperating in a learning program changes the positive attitude towards CAL itself, when no other positive learning effect distinguishes the computer learners from the traditional learners [Rada/Acquah et al (1993)]?

Johnson and Johnson (1986) come to a completely unambiguous conclusion in a comparison of cooperative versus individualistic learning. They find that the cooperative forms offer advantages, and that learners exhibit a preference for cooperative learning: »computer-assisted cooperative learning promoted greater quantity and quality of daily achievement, more successful problem solving, and higher performance on factual recognition, application, and problem-solving test-items than did computer-assisted competitive and individualistic learning« (15). Such straightforward results are few and far between, however. Usually the studies point out that quite a number of variables have not been controlled, without which the result can hardly be interpreted.

Thus the study by Amigues and Agostinelli (1992) points out that with comparison studies of two different models it is also important to consider the degree of familiarity with regard to the comparison condition. They analysed 72 test persons in solving physics problems in an electronic circuit, either singly or in pairs. In the familiar version, no differences could be found between single workers and pairs, in the non-canonical version, however, pairs achieved better results.

Individual learner characteristics also play a part in cooperative learning. Without control of differentiating learner variables, the results may be contradictory and inexplicable. Mevarech (1993) examined 110 third-graders with a performance test, and subsequently let them learn singly and in pairs with a mathematics program in the authoring system CCC (Computer Curriculum Corporation, Palo Alto, CA). For strong students, the method did not make any difference, while weaker students received clear benefits from the cooperative method. The accompanying observation identified the following beneficial factors: discussing problems, recognizing faulty input, getting help in remembering suitable algorithms.

Environments for foreign language learning, in which the communication of test persons with each other understandably constitutes a learning objective area in itself, present a special problem for the examination of cooperation processes. Meskill (1993) examined discourse patterns that arise in such an experiment.

The results of most studies are non-significant, because they do not control said conditions. Elshout (1992) reports on 22 studies on learning in pairs: »only two yielded a significant difference between the conditions of interest. One experiment gave a result favoring working alone, the other one favoring working with a partner« (11). In that case, qualitative studies on cooperative learning like that of Pea (1993) seem more promising. Pea concentrates on observing the processes and products of cooperation in working with his *Optics Dynagrams Project*, and finds that both learning behaviour and learning products are fundamentally different from traditional learning situations.

Hypertext & Monitoring

Studies of learning in hypertext environments can draw on various methods for recording the learning processes, which the respective environment offers for free. Protocolling instruments (»tracking tools«) which follow and automatically register the navigation paths (»audit trails«) of the students are easy to design. We must distinguish between two methods here, passive protocolling and active protocolling [cf. Carlson 1988].

Passive Protocolling

The »Recent« dialogue in *HyperCard*, which records the last 35 cards visited, or the »History List« in other program environments, offer a – mostly meaningless – protocol to the user. These forms of protocolling were initially intended as a further means of guarding against getting lost in hyperspace [s. Schnupp (1992), 68, 167]. In many learning programs, however, it is sensible and even necessary for reasons of learning theory (orientation and feedback), to provide the learner with a more meaningful protocolling method. I have realized a relatively simple protocolling method in the program LernSTATS, an introduction into statistics in psychology [Schulmeister/Jacobs (1994), s. Ch. 10]. The learning environment consists of an introduction to statistics with cross references in hypertext style, of animated formulas, formulas which can be manipulated interactively, two- and three-dimensional statistic diagrams which can be manipulated interactively, and many exercises aimed at objectives like e.g. classifying systems, assigning categories and statements, interpreting curves. All interactions are protocolled (time, exercise, node, mode, frequency, repetition, results). What is interesting about the protocolling is that, apart from chapter and exercise, the number of attempts, modified parameters and the result are protocolled as well. From this protocol, the respective user's learning processes could be reconstructed exactly, and an appropriate tutorial consultation could follow. The learner's protocolled activities could then be viewed and, if desired, deleted, because the protocol is not meant to control the learner (e.g. through the teacher), but only to assist his memory. If the learner lets the protocol stand, the program will next time skip the exercises which have already been done – a very humble form of a program's »memorizing« ability.

In some cases, the protocolling of the learning process can and should go much farther than in the example described, with the program 'passively' protocolling the user's activities, so to speak:

With *AutoMonitor*, Macleod (1992) presents a *HyperCard* application that is supposed to enable a monitoring of learners. *AutoMonitor* protocols the user's navigation and the navigation tools used by him. The protocols are exported in the form of TabText files, and can be analysed statistically with the help of Excel templates [s.a. Kornbrot/Macleod (1990)]. De Young (1989) presents a protocolling method in hypertext with the example prototype EWP (Electronic Working Papers), realized in Lisp on a Macintosh [s.a. De Young (1990)]. Williams and Dodge (1993) also present a *HyperCard* program for auditing and tracking. Nielsen (1995) reports on an elaborate auditing software by the Price Waterhouse Technology Centre (1989), which he qualifies, however, by saying: »This figure illustrates a prototyping effort, which does not necessarily reflect current or future audit methodology or practice« (81ff).

Audit trails play a central part in Brown (1985), not as a simple recording method for user interactions, but as source material for tools which will be able to shift the focus from product to process (182), a necessity arising in connection with the constructivist shift of emphasis from algorithms to learning environment. A tool for audit trails that visualized the student's solution path in the form of a tree diagram was already integrated in *Algebraland* (197).

Gay and Mazur (1993) describe sophisticated tracking tools, used and partly developed by the Interactive Multimedia Group at Cornell University, in application to three programs: »Bughouse«, on the topic of insects, »El Avión Hispano«, a story for learning Spanish, and the »Networked Multimedia Collaborative Design Environment«.

Active Protocolling

We have an 'active' form of protocolling when learners can copy information (pictures, text passages and data sequences) from the program, paste them into their own protocol, and then restructure this information or add their own comments and notes in the same or another program. In this case, protocolling would serve the active cognitive processing of what has been learned, an important aspect of the learning process that is all too often neglected when learning environments solely suited to reading and leafing are offered. Let me explain this using the example of the »Dictionary for Computer Terms with Signs« (s. Ch. 8): In designing this program, I was faced with the problem that the user would not want to work with the entire set of data comprising 1.600 terms and sign film clips, but only with a selection. The terms are assigned to generic terms, are grouped hierarchically, but nevertheless the user might find it more practicable sometimes to work with only a small selection of the terms, thus e.g. if the teacher is preparing a lesson for the following day, if the student wants to repeat the last lesson, if a selection of terms is needed for an essay. The user should therefore be able to set up individual lists of terms, supplement insufficiently explained terms with his own comments, assign several terms to a category etc. He must also be able to set up several such selections, and to save and reload them if necessary. For this purpose, the learning program must be able to write the information copied or entered by the user to a floppy or hard disk and save them. This is one argument why hypertext, too, should be able to 'memorize' and 'write' something.

A similar distinction of passive and active working is applied by Carlson (1988): Apart from annotations, the user can also create nodes and links. This leads to an individualization of the product (104).

These methods are only in their infancy. The broad range of questions which could be studied with the help of such methods has hardly been discussed as yet: What kind of information about learners and their learning processes can I gain in this way? Does the restriction to externalized learning processes inherent in these instruments automatically lead to limited interpretations? Are such monitoring applications more likely to produce »information garbage«, or meaningful information? Misanchuk and Schwier (1992) discuss the function of »audit trails« for the formative evaluation of instruction materials, learner performance, making decisions about the attractiveness of certain paths to users, and the purpose of advising learners. They also discuss methods of analysing »audit trails«.

Guidelines for Hypertext-Design

The term »design« can assume several meanings: it can refer to structured blueprints and planning methods for learning systems [Garzotto/Mainetti et al (1995)], or to the user-oriented layout of screen, navigation, exercises etc. [Hardman (1995)]. From a questioning of *HyperCard* stack designers carried out by Nicol (1988) it becomes clear that only very few of them systematically map out their design in advance. Dillon's (1991b) recommendations for the designing process refer to the first aspect, and after giving a summary of the studies on reading behaviour and navigation in hypertexts he formulates the following:

- »Know the users, their tasks and the information space […]
- Plan the structure of the information space […]
- Design suitable access structures.
- Optimize image quality.
- Test the design and test it early! Adjust accordingly« (101ff.).

The recommendations of Brooks (1993) for the design of commercial applications refer to the second aspect: (1) minimize atomization, so that the documents look simple and are easy to use; (2) create a universal iconic representation that meets both the sponsor's ideas and the users' expectations; (3) enable easy access to stored information; (4) minimize the necessary effort, technology and resources.

Design in hypertext environments should keep four functions in mind: user orientation, navigation method, increased semantic value of the system for learning success, and support of active learning processes. These criteria are not clearly distinguished in writing on the subject. The first two criteria correspond to what appears in the literature as »usability« research. There are hardly any studies on the other two criteria other than evaluation studies. The terms mentioned by Gay and Mazur (1991), *learnability*, *usability*, *consistency*, *flexibility*, apparently aim at a similar distinction of criteria.

»Usability« criteria for hypertext systems have been formulated by Nielsen [(1995), 279ff]: Easy to learn, efficient to use, easy to remember, few errors, pleasant to use. Especially important to Nielsen is one distinction that is seldom checked in evaluation studies: the distinction between social acceptability and practical acceptability, and the differentiation of »usefulness« into »usability« and »utility«. One can already recognize at this global level, at which terms like 'easy', 'efficient' and 'pleasant' appear, what problems may be expected in an operationalizing of design criteria.

Frequently, design guidelines for hypertext are values that are difficult to interpret: thus Shneiderman et al (1991) for example formulate criteria like »provide details on demand«, »produce just enough information initially to ensure comprehension«, »present just enough information at each stage« [s.a. Kreitzberg (1991)]. Expressions like 'just enough' or 'adequate' are indicative of the problems of judging and interpretation that are inherent in design guidelines formulated in this way. The question is whether designers can make any sense of these criteria.

The 10 criteria by Ben Shneiderman (1989), in which however recommendations for designing process (1, 6, 7, 9) and product structure (2, 3, 4, 5, 8, 10) are jumbled together, come closer to hypertext features:

1. Know the users and their tasks
2. Meaningful structures come first
3. Apply diverse skills
4. Respect chunking
5. Show inter-relationships
6. Be consistent in creating document names
7. Work from master reference list
8. Ensure simplicity in traversal

9. Design each screen carefully
10. Require low cognitive load (125ff.).

The recommendations reported by Search (1993) from the experience of designing his *HyperGlyphs* project are similar: recognizing the limitations of the medium, identification of several levels of authorship, defining and visualizing the semiotic model of the application, spatiotemporal cards and individual references, restriction of functions that are meant to protocol navigation behaviour.

In the following, I would like to formulate 10 recommendations on various questions of hypertext design, which are based on my own, unsystematic experience with hypermedia applications, but for that very reason are perhaps somewhat more concrete than the general criteria I have cited:

Start and Introduction

A popular element in hypertext systems is an extensive title sequence, in which the authors introduce themselves in written or pictorial information, or announce the topic to a flourish of trumpets. It is rather annoying, however, if the learner has to plough through these lengthy titles every time on starting the program, before coming to the application proper. Many authors have thought of something here, like e.g. »Press Control and Space key in order to skip titles«. Unfortunately, the learner often discovers or remembers this trick too late to prevent the title sequence from launching. It would be much more sensible if the program could remember the user and skip the title sequence at the next program start. The authors of the program could always fit an option into the table of contents that causes the 'unforgettably beautiful' intro to be played when clicked [s. Minsky's »The Society of Mind«].

Information Units

An unsolved problem in hypertext systems is the size of information units, the so-called grain size or granularity. In some systems, the systems themselves determine the size of the units, like e.g. the page in a scroll window in *Guide*, the card in *HyperCard*.

A similar question concerns the upper limit, the maximum threshold value for the number of links. What criteria decide on a. all possible links, b. all meaningful links? Can the design problem of hypertext be solved by a limitation of links? Do hypertexts that only know meaningful links not turn into Kiosk systems with return option and roundabout traffic?

Do we need a semiotics of hypertext and a rhetoric for electronic books? »We face, possibly for the first time in textual history, a grammar of really new characteristics and demanding new answers« [Gomes/Pereira (1992), 94]. But after a reference to classical rhetoric, Carlson (1988) comes to the conclusion: »No such 'rhetoric' exists for hypertext« (96). She wonders if this would have to develop around the aspects modularizing, node size, and »grammar«, i.e. guidelines for composition. Gomes and Pereira, who postulate three grammatical levels, are in search of such a grammar: »a first level (the sentence grammar); a second level (the text grammar); and a third level (the hypertext grammar)« (94). They only ask questions about the semiotics of the third level, however, e.g. can links be interpreted as anaphora, cataphora, deictic, rhema, message, context?

Practical considerations for the size of hypertext units and number of links cannot be set down without considering the respective contents and context within which they appear: Narrative units may be larger than lexical ones. Units that are supposed to be transferred over a network, as in the World Wide Web, should be restricted to screen size, so that the loading time does not become too long, and the user can see everything at once. Hypertext interfaces that work with clicking and pointing within the text in a way collide with scrollable window contents.

Separation of Authoring and User Environment

There are some learning programs whose developers are apparently convinced that it makes sense to bar access to the menus of the developing environment to the user, in order to get him to use only those navigation tools offered on the screen. I do not deny that there may be serious reasons for this. But in most cases I have looked at, it seems that what tipped the scales in favour of hiding the menus, and treating the user like a child through inflexible navigation rules, was not so much factual reasons as the developer's intention to offer an application that at first glance looks like a stand-alone application.

I have chosen the same way in the case of my *HamNoSys Editor*, however. This editor serves to transcribe sign language in a scientific, grammatical notation. It relieves the transcriber of the trouble of having to remember exactly the close to 300 symbols in the HamNoSys font and their position on the keyboard, and to have to observe an exact order in transcribing a sign into a HamNoSys string. The user is guided by the grammar, so to speak, to execute the correct next steps. The more than 160 cards are networked by way of buttons and procedures according to grammatical prescriptions. Since the initializing procedures are not the same for all cards, the program running behind the cards might be disturbed if the transcriber would find his own way through the stack with the help of HyperCard navigation tools. For this reason I have hidden the menus and bypassed the navigation commands contained in them. The user can only choose the navigation tools offered on the card itself.

Backward Navigation

In the case of my *HamNoSys Editor*, the grammar program running in the background would be disturbed if the user fell back on the *HyperCard* menu commands. I have therefore developed my own method, which might be called »backtracking« or »backwards navigation«: Each card has an invisible field into which the card that the user has come from is entered on opening. Each card also has a "go back" button, which reads the contents of that field and then jumps to the card noted there. In this manner, the user can backtrack the entire path, even going beyond the 35 cards offered by *HyperCard*, and can go back to earlier stops without destroying the transcription logic. The program knows which steps of the transcription process have to be reversed. The restriction of navigation is justified by the cause.

But backtracking also makes sense as a method beyond such contexts, in programs that allow entirely free navigation as well. Nielsen (1995) distinguishes five different kinds of backtracking, and presents a number of different hypertext applications that have developed interesting backtracking methods (249ff):

Chronological	backtracking the original sequence step by step
Single-Revisit	stops that were visited more than once are only visited once in backtracking
First-Visit	the stops are only visited once, but in the sequence of the forward path
Detour-Removing	detours and loops are not backtracked
Single-Revisit with Interrupted Sequence	backtracking can be interrupted and then resumed afterwards.

Backtracking is necessary and should correspond to the user's needs as precisely as possible, because navigation is very much about orientation on the one hand, and the heuristics of learning on the other. If the learner cannot establish his own orientation and does not receive any feedback on this aspect, he will be annoyed and neglect his heuristic attempts in order to put all his energy into the question whether this 'tricky' navigation system cannot be trikked itself, be 'cracked' in some way, or he gives up and quits the program.

History

The »History List« [Nielsen (1995), 254ff] is distinguished from backtracking. The history list is a record of the hypertext nodes visited, often in the form of mini icons of the relevant screen pages, or in the form of menu entries. The history list allows the user to go back directly to a stop visited earlier without having to backtrack all of the sequence. In this sense, *HyperCard's* »Recent« dialogue is really a history list. With the help of this navigation method, the user of an extensive application can quickly return to the starting point of his intellectual journey, if he has lost his bearings. The history list is an additional means of backtracking. Some programs arrange a history list in the form of a bar with the last five or six screen pictures in miniature format the bottom of the screen, in which, like in a stack, the first picture is always replaced by the most recent one.

User-Defined Navigation Paths

The learning environments offered on the market become more and more complex. More extensive examples are shipped on CDs. One can imagine that in such environments the learner's orientation cannot be assured without some effort, and that the possible methods of navigation through the various parts of the program can no longer be easily designed. If interaction is not handled restrictively, some arguments against which I have already cited, free navigation can become a problem. One can counter this by enabling the learner to write down the paths he has taken, and repeat them through a simple call. WWW browsers allow the marking of individual pages, whose path is then included in a menu.

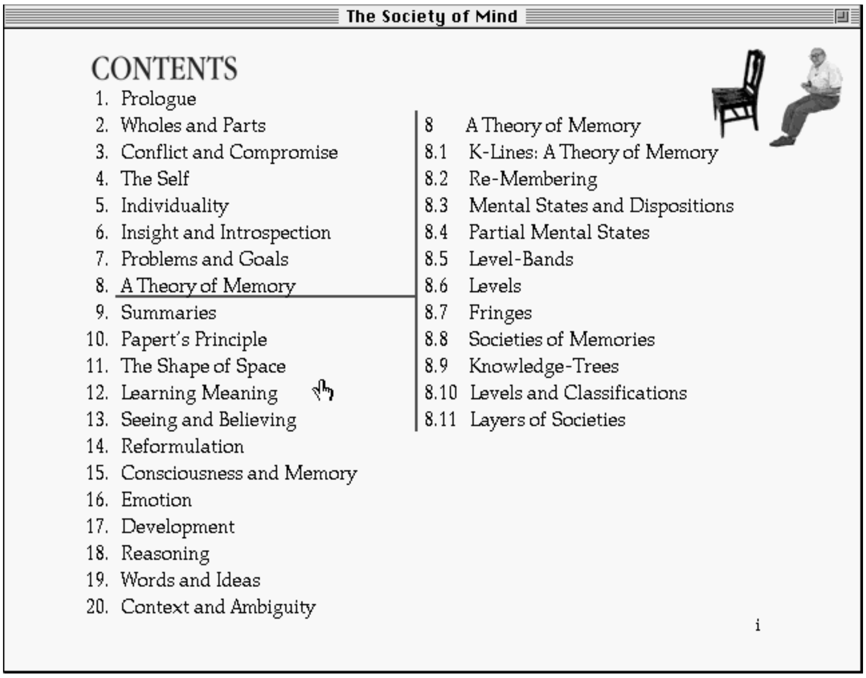
The program must store the path chosen by the learner, and be able to recall it on demand. With particularly complex environments, it is important that several paths set down by the user can be loaded alternatively. In most systems, such methods can be realized quite easily by using a script to call a routine which places a navigation button on the current starting card that automatically leads to a second card to be chosen. Or the cards chosen by the user are written into a file which can be reloaded into a field or menu (examples for this can be found in *Culture 1.0*).

Paradoxically, the best navigation method for children's books is not the 'secure' one restricting navigation to simple forwards and backwards steps, as in Kiosk applications. In animated children's books like those by Brøderbund, there are a whole lot of things to be discovered, many objects to be clicked. Navigation may be »confusing« here and does not have to be »simple«, as one would expect for children (no button is in the same place on each page, sometimes an object can be taken out of a drawer, sometimes not), because navigation in animations is determined by the pictorial contents. Behind this topmost level of the user interface, however, uniform navigation principles should be chosen (e.g. single click instead of double click), which remain quasi invisible to the child.

Navigation Assistance

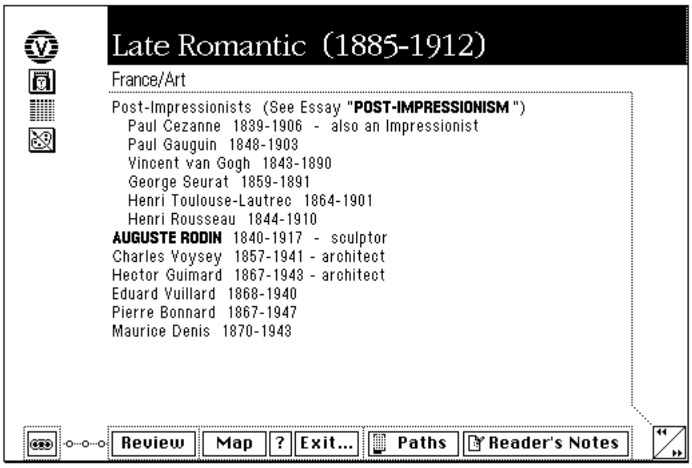
Shneiderman (1989) recommends the construction of a document especially for the introduction of a hypertext which has links to all other documents, a kind of table of contents (»menu strategy«) or glossary (»glossary strategy«). This root document should be organized hierarchically (»top-down strategy«), i.e. it should be based on headings for the rest of the text. In Marvin Minsky's »The Society of Mind«, the table of contents is such a root document. If the user clicks on a chapter, a list of the subchapters appears to the right of the list of chapters.

FIG. 26
TOC with Fisheye view from Marvin Minsky's »The Society of Mind«



Hannemann and Thüring (1995) recommend, especially with layered hypertext, always making clear to the reader at which level he is (38). Let me give an example from *Culture 1.0* here. As soon as the reader has reached the lowest level of the hierarchy, the levels traversed on the way are represented as icons in the left margin, and the reader can return to he desired level with a mouse click. In the example illustrated, the icons symbolize the level »Art«, the epoch »Late Romantic«, and the overview of all epochs in *Culture 1.0*:

FIG. 27
Culture 1.0:
The Icons in the Left-Hand Margin Symbolize the Levels



In another context, I had already pointed out the trend to supply hypertexts with overview diagrams, so-called maps. Automatically generated diagrams for the contents or links in a hypertext can become too extensive and too diverse, and thus become useless [s. the illustrations in Nielsen (1995), 265ff]. In such cases, one tries to get by with fisheye views, with zoomed excerpts. Overview diagrams that do not reflect the contents of the application seem meaningless to me. Thus geographical maps belong to topographical systems, spatial diagrams to surrogate travels, and logical diagrams to argumentative texts. The metaphors used in such environments must be matched to this as well [Nicol 1988].

Storing Data

Since the CD-ROM offers itself as a medium for multimedia environments, more and more learning programs are put on the market which are stored entirely on a CD. The intention behind this is understandable. How comfortable, after all, for distribution for example, to be able ship the current program version, all application documents, all pictures, all animations, films, and the respective driver files on a single CD of 640 MB! Since, however, the CDs thus distributed are non-writable mass storage media, a number of consequences with regard to the above comments arise. If the programs memorize anything at all, they only do so for the duration of the current run in working storage. When the program is called up again, the information is lost.

Yet it is reasonable that effective working with a learning program presupposes an individual processing of what is presented. The learner must be able to take home data and information from the learning program, e.g. pictures, texts, tables, and curves resulting from calculations and simulations. It makes sense not only to offer learners the option to print out this information, but to process it in the computer with the help of this or another program. Among the data and information that a learning program should be able to memorize at the very least are:

- the user name
- the protocol file kept for the current user
- the information copied by the user
- the user's notes
- the files registering thepaths created by the user.

It would be quite easy for any program on a CD-ROM to ask for the name of a hard disk in a dialogue in order to store the desired data on that disk. The user could then go back to them next time without any problem.

Interaction

Two extreme forms of interaction in hypertext can both lead to a flagging of the learners' motivation:

- The rigorous restriction of navigation to »leaf-turning«, which is strongly reminiscent of the Programmed Instruction style, creates a feeling in the learner that he is being controlled by the program, and makes learning motivation flag.
- Free navigation with an enormous amount of information without a suitable progress indicator can induce learners to feel that they are being overtaxed, and thus can lead to loss of motivation.

Nothing could be more boring than a hypertext program that willingly reacts to each of the user's navigation commands, but does not show or provoke any other kind of reaction. It is the specific task of outstanding learning materials to challenge the user into action, to coax him into active learning and get him out of a merely receptive attitude. It is relatively easy to create opportunities for active behaviour on the learner's part, even if it means more work for the programmer. To realize the reverse direction of interaction, to let the learning program react to the learner's activities, is much more difficult, however. We can distinguish at least two forms of program interaction with the user here, a *formal*, and a *thematic* one:

- By a *formal* program reaction, I understand messages and information given to the user by the program, which in the form of preplanned dialogues follow upon foreseeable punctuating by the user. This could be tips for navigation, heuristic tips, or methodical advice. A prerequisite for meaningful interaction is that the program provides varied exercises, tasks, and constructive activities for the learner.

- By *thematic* program reaction, I understand dialogues and hints which depend on the contents of the current interactions. They generally presuppose an analysis of the interaction texts (input, reaction to dialogues, other screen actions) and a set of rules in the form of an expert system, which can be realized for only a few situations, since most actions imply heuristic, cognitive, learning psychology, and educational dimensions.

Apart from an analysis of the subject matter's content, thematic feedback also presupposes predictability of individual learning prerequisites, an evaluation and typology of individual learning strategies and possible cognitive slips, i.e. a kind of learner and user model. Knowledge of this kind at best exists on a general level in psychology, not with regard to individual subjects. Even for sciences like mathematics or physics, there is nothing in the manner of a heuristics of learning for these subjects.

Feedback

It is a relapse into the era of Programmed Instruction if the authors, out of a lack of educational imagination, cannot think of anything other with regard to feedback methods than asking a question, providing a choice of three answers, and testing whether the correct one was chosen. The multiple choice method is a death-blow to any independent learning process. This is not always the case, however, as the Beethoven program by Robert Winter (The Voyager Company) demonstrates: Although the test part of the program does not differ from behaviourist models in terms of method, the program, which deals with music, of course has an easier job in a number of ways:

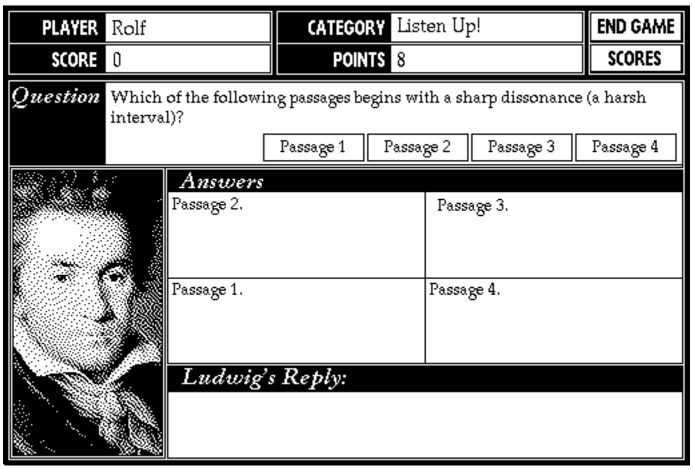


FIG. 28
Test on Beethoven's Ninth Symphony with Audio Excerpts

It can present music samples, play several variations on the same theme, and ask in which order the themes appear in Beethoven's

Ninth Symphony, in which passage a certain musical structure is used or a particular instrument occurs, or which passage introduced an important innovation in musical history. The multiple choice questions become more sophisticated through the music samples, they are turned into an exciting game, and thus are hardly recognizable as multiple choice.

Once one has grasped how varied feedback in the learning process may be, there is little problem in thinking of suitable feedback methods for the respective topic to be dealt with. Feedback in hypertext systems usually starts with such simple things as varied visual and acoustic signals as reaction to navigation and other commands by the user (highlighting selections in text fields, auto-highlighting of buttons, fade effects in window switching, sound signals for mistakes, digitalized speech output etc.). The effects also lend themselves extremely well for turning the user's attention to thematic aspects of the learning process (e.g. flashing on exceeding certain values, highlighting active parts of a formula or newly calculated values, spoken alerts).

More exciting, however, is *thematic* feedback, which emerges from the subject or a knowledge of learning processes. It is often overlooked that the result of a search process, the result of a calculation, the graphic curve of a simulation, are forms of feedback in themselves, which often suffice to motivate the learner without the need for further remarks or formal feedback. There is rather a need for helpful advice when the desired result fails to appear in several tries, in order to avoid frustration. This example points even more towards the importance of enabling active behaviour and providing exercises for the learner. Mere leafing or reading will not yield casual opportunities for unobtrusive feedback. These only arise when the learner is allowed to manipulate the data and information on his own. A descriptive statistic analysis of navigation steps is easily realized, as is a simple analysis of a learning protocol (which exercises were tried how often with what results). Beyond that, however, especially with certain scientific subjects (textual analysis, literary studies, history, and history of culture), qualitative, individualized feedback becomes much more difficult.

CHAPTER 8

The Rhetoric of Electronic Books

Basic Features of Electronic Books

In terms of concept, electronic books are hypertexts with »constraints« (less, reduced, or schematized links). The motive for keeping the traditional metaphor apparently is the designers' wish to exploit the user's familiarity with the conventional medium: »Although electronic books require new skills, the learning curve for initial familiarization with hypermedia or electronic books appears to be relatively shallow« [Woodhead (1991), 63]. Benest (1991) aims at avoiding apparent disadvantages of hypertext in the raw (getting lost, cognitive overhead, and tunnel vision). As a remedy, he looks to typical characteristics of books: only displaying one page at a time, scrolling text, a succession of screens as in leaf-turning. The book metaphor does, however, not only have advantages, but considerable disadvantages as well [Bornman/von Solms (1993)]:

- »it provides a weak mechanism for the presentation of more complex semantic relations that can be identified between information pieces;
- it has a linear nature and will thus never be able to present complex relations effectively« (264).

Apart from experimental versions of hypertext systems (*Zettels Traum*, cited in Kuhlen (1991), or »Hypertext Hands-On!« by Shneiderman and Kearsley (1989), which was published as both book and hypertext and is intended as a demonstration of the topic), no one to my knowledge has as yet written a book that was not published in printed form first. Moulthrop (1992) calls this type of electronic books, which replicate printed books, »hypertext retrofit« (172). The Intermedia examples are perhaps still the best representatives of the type that Moulthrop calls »native hypertext« (173). These examples are not designed as electronic books, however. Nielsen (1990) points toward Wurman's (1989) book on »Information Anxiety« as an example for a designer book that has hypertext characteristics: »If ever a book was suited for hypertext publication, this is it« (275).

McKnight, Dillon et al (1991) also state: »To the best of our knowledge, the book which has only been distributed in hypertext form has yet to arrive« (11). But there is a tremendous difference between editing an existing text for hypertext presentation [there are procedures which take care of that automatically, Kuhlen (1991), 160ff] or composing a text directly for hypertext. The concept of electronic books surely does not cover projects like Chomsky's (1990) of simply putting books on laser disc and having them read to the users. The hypertext principle must be a basic feature of electronic books.

Barker (1992a) distinguishes eight types of electronic books: textbooks, static picture books, animated picture books, multimedia books, hypermedia books, intelligent electronic books, telemedia books, imaginative books, and books »that are based on environments that support artificial reality« (133); s.a. Barker and Manji (1991). Barker and Giller (1990) stress that other than in real books, the pages of electronic books do not have to exist as such, but can be generated in real time (13). Electronic books can therefore be reduced to a database and retrieval system, which could intelligently adapt to the user's habits (1ff.).

Structural Elements of Electronic Books

The book metaphor is supported by several technologies: Sony with its small portable encyclopaedia machines, Xerox PARC's Dynabook [Kay/Goldberg (1977); Kay/Goldberg (1988)], *Guide*, and Voyager's *Expanded Book Toolkit*, which was developed on the basis of *HyperCard*. Barker (1992a) subdivides the structure of electronic books into »root pages«, secondary pages, the linear course, the excursion, and the separation of argument and data (134ff.).

The Voyager Company's *Expanded Book Toolkit* is a sophisticated extension of *HyperCard*, which automatically transforms imported texts into book form, allows creating links in a very easy manner, and automatically realizes additional navigation elements like notes, annotation windows, tabs and markers, as well as an indexing of the text and several comfortable searching procedures. The *Expanded Book Toolkit* knows the following components, among others: paper clips for marking text pages, and a search menu that opens over any term in the text and supports not only a simple search for further instances of that term, but also searching for the term in context.

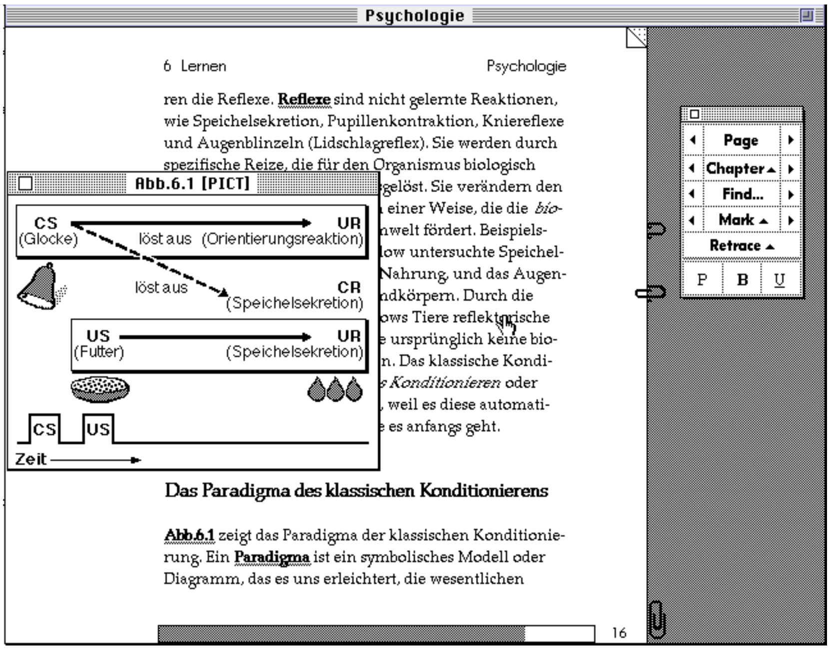
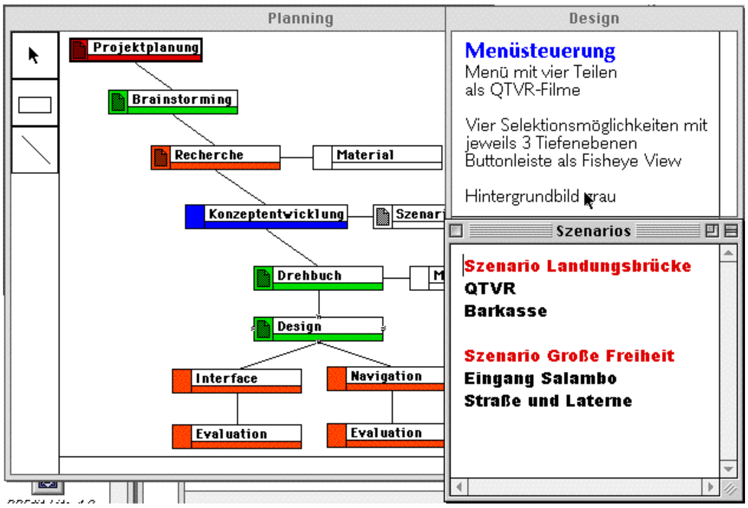


FIG. 29
Example from the *Expanded Book Toolkit*: Book Page, Graphics Window, Navigator, Paper Clips

The *Book Emulator* by Benest (1991) provides the following components of electronic books: graphics, navigation tools (bookmarks), annotations, table of contents, index, schematic diagrams, conferences, »parental control (a parent process with communication links between parent and child)«. Benest (1990) describes the Book Emulator as a book-like variant of a computer supported learning program which has annotations and highlighting in the text, bookmarks, a table of contents, and an index. His program does not aim at the electronic book, however, but at computer supported exercises.

WEBSs is a general hypertext tool that was developed especially for the creation of electronic books [Monnard/Pasquier-Boltuck (1992)]. WEBSs works with object-oriented structural diagrams, has its own scripting environment, and thus provides improved functionality for the user. Scripts in WEBSs can be coupled to objects and to classes of objects. In the browser tree structure, nodes can be linked to one or more documents. Complex calculations and manipulations can be carried out by way of logical mathematical models, so-called Markov-strings or models of linear optimization.

FIG. 30
WEBSs: Structural Diagram and Text Window



Landow (1989a) presents a set of 19 rules for authors of hypertext systems which he calls the »rhetoric« of hypertext, and which are meant to serve the readers' orientation. The rules are strongly influenced by the rich possibilities of Intermedia. They are modelled on the travel metaphor. Thus Landow speaks e.g. of the rhetoric of departure and arrival. But the rules are not presented in the form of a rhetoric, but are rather relatively vague and general, e.g. that the existence of links stirs up the reader's expectation that there will be important, meaningful relations between the linked materials, that links stimulate the reader's relational reasoning, that documents which disappoint the reader's expectations are experienced as incoherent, that the author should always provide several options of navigation components like networks, outlines etc., that the navigation elements should always be bound to text or graphics and should not be floating freely, that all links should be bidirectional, that the destination of a link must be transparent to the reader, that graphics should always be accompanied by text etc.

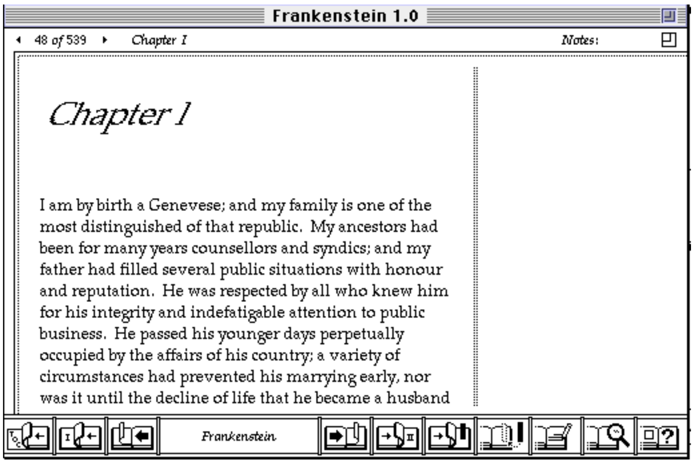
There are already a lot of such suggestions for the structure of electronic books. Thus e.g. Monk (1989) argues for a personal browser, a table of contents listing the nodes that the user has visited. Olsen (1992) outlines a design for bookmarks directly in and on the scroll bar. Free format annotations and a Magic Marker for marking text passages are proposed by Nielsen (1986).

Examples of Electronic Books

»The Masque of the Red Death« [Harris/Cady (1988)] is regarded as one of the first electronic books: this is already a book with buttons, graphics, and sound.

The electronic books classics collection of Dartmouth College is offered free in the Internet. These are books which have been provided with a number of search functions, but otherwise consist of the bare text of the English and American classics.

FIG. 31 Mary Shelley's »Frankenstein« (Dartmouth-Collection)



I would like to present two examples that demonstrate what possibilities electronic books can realize, and the various design options that are available in doing this:

Marvin Minsky: The Society of Mind

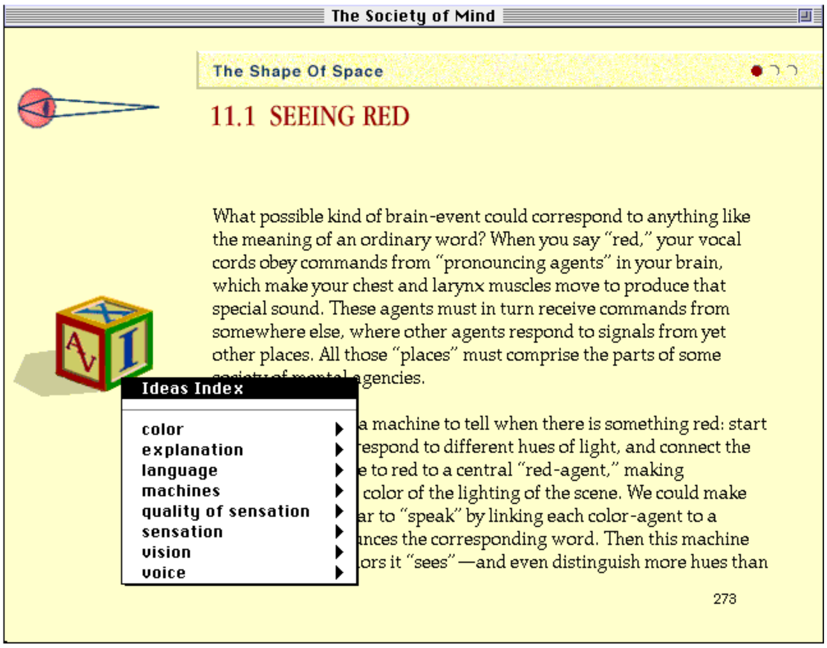
The book is accompanied by Marvin Minsky as presenter, and supplemented by a timeline and films with experiments.

Stephen Hawking: A Brief History of Time

The book is accompanied by a host of animations with explanations on philosophers and physicists, physics theories, a biography of Einstein, and further films.

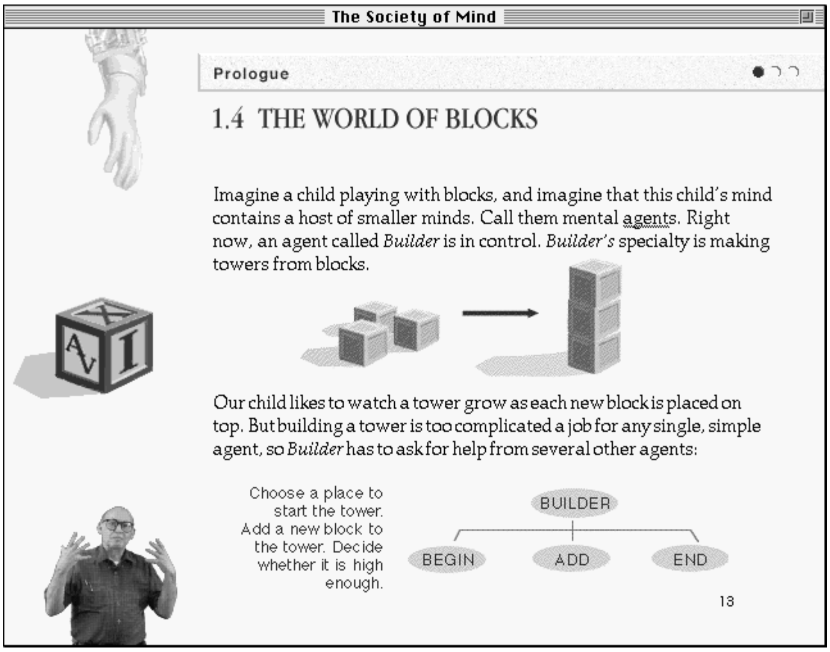
Marvin Minsky: The Society of Mind

FIG. 32
The Book Layout of Marvin Minsky's »The Society of Mind«



The cube, a building brick from a child's box of bricks, symbolizes Minsky's »Building Block« theory of artificial intelligence, and with its three visible sides at the same time serves as a three-part menu for stories (»X«), films (»AV«) and thematic aspects (»I«). Popped up is the »I« menu for thematic aspects, the »Ideas Index«, whose entries refer to other chapters or sections of the book. In the upper bar of the window, there is the title of the chapter, which when clikked opens a menu with the contents of the entire book. The three bullets to the right of the title bar are for page-turning. The basic structure of »The Society of Mind« is clearly supplied by the traditional book. The other elements are an additional »expansion« of the text. Such an expansion can be seen in the next illustration: Marvin Minsky in (first) person introduces, in an idiosyncratic style of presentation, the basic concepts of his theory:

FIG. 33
Marvin Minsky as
Personal Presenter



In the bottom left corner of the screen, Marvin Minsky appears as a digital video insert. There are films with Marvin Minsky as presenter for each chapter. In the »AV« menu of the cube, there are also some historical films on Marvin Minsky's early experiments. This page of the book shows how the book was supplemented with illustrations. Other elements of the book's CD version expanding (»enriching«?) the text are

- a graphical representation of stations in his life (timeline): Films, speeches at conferences, texts and pictures can be called up for the individual stations;
- an excursion into Marvin Minsky's study, in which the visitor can play some short films that illustrate Minsky's personal environment (travel souvenirs, his harp, his personal Macintosh).

Stephen Hawking: A Brief History of Time

The CD of Stephen Hawking's book »A Brief History of Time« does not start with Hawking's book, but with an image of Stephen Hawking's room:

FIG. 34
Stephen Hawking's
Room

To the left is a spacecraft control room. On the wall hangs a honeycomb, whose compartments stand for chapters of the animated version of Hawking's book. Access to the electronic version of the original book is gained by way of the book lying on the desk in front of Hawking. On the desk is a tortoise that has a story of its own. Behind Hawking there is a picture on the wall, which tells the life story of Albert Einstein. Hawking and his chair supply information about Hawking himself. The visitor may turn, and will then see the other half of the room with further interactive components.

The book with its 11 chapters is available twice on the CD. Once as a traditional book in electronic form, and then again in the form of animations. The honeycomb on the wall of Hawking's study gives access to the chapters of the animated version of the book. These animations offer an immense wealth of examples and illustrations that are well-designed, of a high standard with regard to contents, and suited to the topic. One can jump back and forth between the text version and the animated version at any time.

FIG. 35
Hawking's Book as
Honeycomb

In the text version, small picons in the right margin of the text serve to switch from original book to the animation version. For switching from animation to the original book, every animation offers a book icon at the bottom. Each animation is introduced by a picture with the chapter's organization.

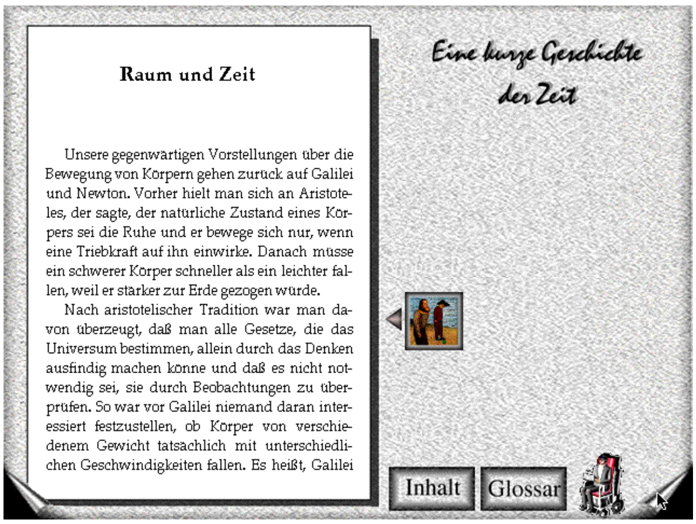


FIG. 36
»A Brief History of
Time« as Electronic
Book

FIG. 37
Animation on the Theory of Relativity

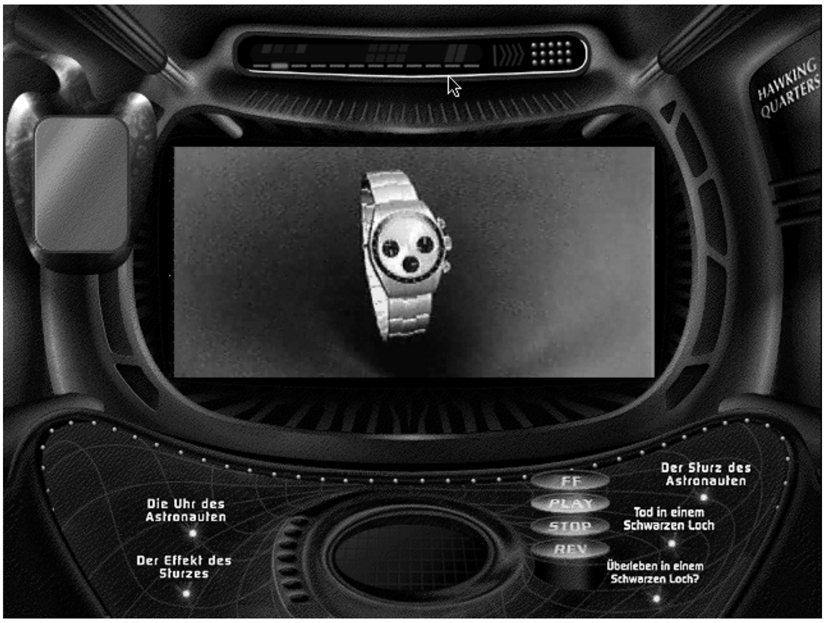
FIG. 38
Organizer of the Chapter on the Theory of Relativity

The above illustration shows the organizer for the chapter »Relativitätsstraße« [Road of Relativity] . From these chapter organizers, the reader can access any animation item directly. The animations all have a menu bar with icons at the bottom of the screen which covers all navigation options: turn page, return to the text, return to Hawking's room, single frame mode, sequential mode.

One can imagine that the animations, the complete »second book« on the CD, do not cover the exact same contents as the text version. But the authors have taken the greatest possible care to aim at two particular objectives with the animations:

- To bring even more comprehensibility into the description of the theories which are treated by Hawking. I say »even more«, because the original book was already said to have succeeded in addressing a wide range of readers.
- To explain in depth historical facts and premises from philosophy and natural science which are only mentioned in passing in Hawking's book: Thus there are chapters with animations on all famous philosophers and natural scientists, on the origin of the universe, on black holes.

FIG. 39
The Spacecraft Cockpit with an Animation



This CD shows better than Minsky's book the advantages an electronic book can have. Minsky's CD pursues an »additive« concept, i.e. the book is expanded with new elements, the Hawking CD pursues a »multiplying« concept, i.e. the new elements are serviceable worlds of their own. In this case, the CD contains completely different, but complementary versions of a book, one of which versions it would not make any sense to print. One may suppose that the book can also address new and different groups of reader, who would not have been reached by the original book: young people, and readers of the book who wanted to have explanations for many of the premises that are unexplained there.

Dictionaries and Encyclopaedias

Comparison of Two Sign Language Dictionaries

With the Dictionary of Computer Terms with Signs [Schulmeister/Prillwitz 1993; Schulmeister 1993a] published in 1993, and the ASL Dictionary [Sternberg 1994] published in 1994, we are now looking at two dictionaries on CD-ROM. A direct comparison allows us to discuss, by way of a concrete example, what design principles electronic dictionaries may pursue. Both dictionaries want to offer the user direct access to individual signs. But all other aims of the designers seem to be different, which gives an interesting insight into the range of possible aims that this technology offers to the dictionary user.

The Dictionary of Computer Terms with Signs

On opening, the *Dictionary of Computer Terms with Signs* presents the user with a page of two lists of terms and a number of buttons for a variety of functions. The list »Begriffe« [terms] contains 1.500 terms related to the topic of »computer technology«, the list »Oberbegriffe« contains ca. 30 generic terms to which the 1.500 individual terms have been assigned. At first glance, the whole thing does not seem to have anything to do with signing. And the basic function of this dictionary consists of choosing one of the terms in the list and look at the dictionary entry for that term. The dictionary entry consists of two fields: a definition, and an example sentence, in which the currently chosen term occurs. For an individual term, the screen looks like this:

The basic function of this dictionary is obviously a » traditional« one: The dictionary consists of a register with terms and definitions. All further functions are »sleeping« behind the buttons of the con-

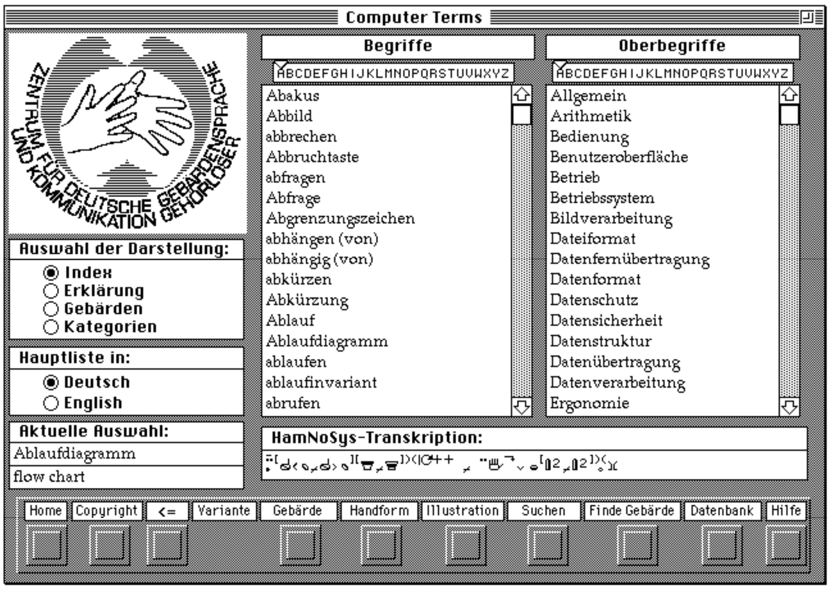


FIG. 40
Basic Page of the Dictionary for Computer Terms

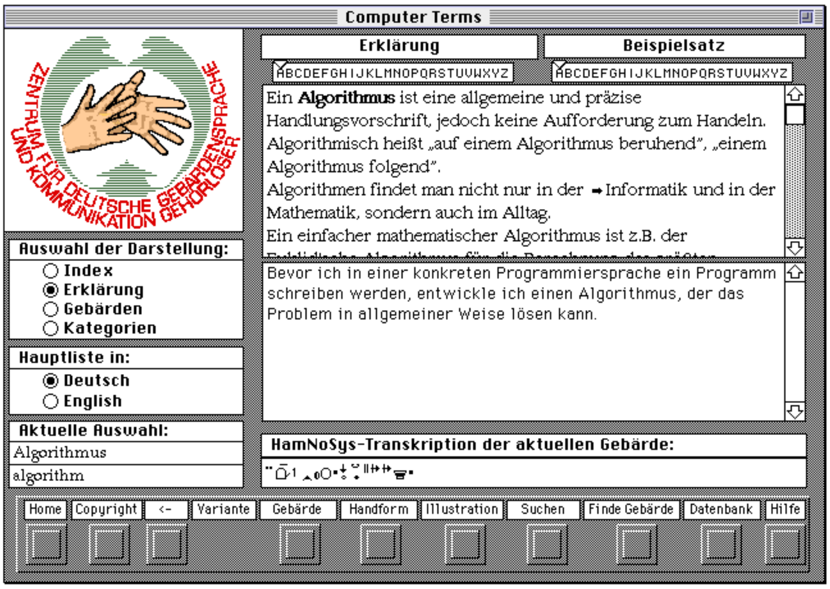
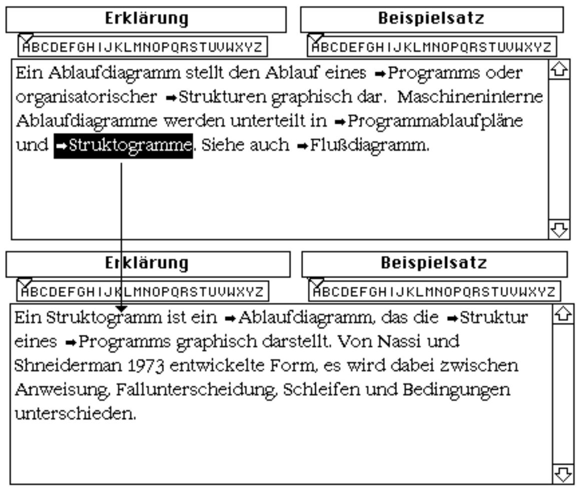


FIG. 41
Explanation and Example Sentence for the Currently Selected Term

trol bar at the bottom of the screen. At this point the question may arise what advantage the electronic form has for such a dictionary. Let me give a brief explanation: Term definitions in a dictionary usually depend on each other. One term is explained by way of another. A program can handle this network more successfully than a book. The terms in the dictionary are linked in the form of a hypertext. If one selects a term in the text of a definition, the program

»jumps« to the definition of that term. This jumping process is illustrated in the next screen through two definition fields placed above each other:

FIG. 42
Hypertext Function in the Dictionary for Computer Terms



Hypertext makes the network of relations between the terms transparent and more easily manipulable than the index of a book could. The *Dictionary of Computer Terms* in its basic form thus proves to be a traditional dictionary with hypertext functionality.

The ASL Dictionary

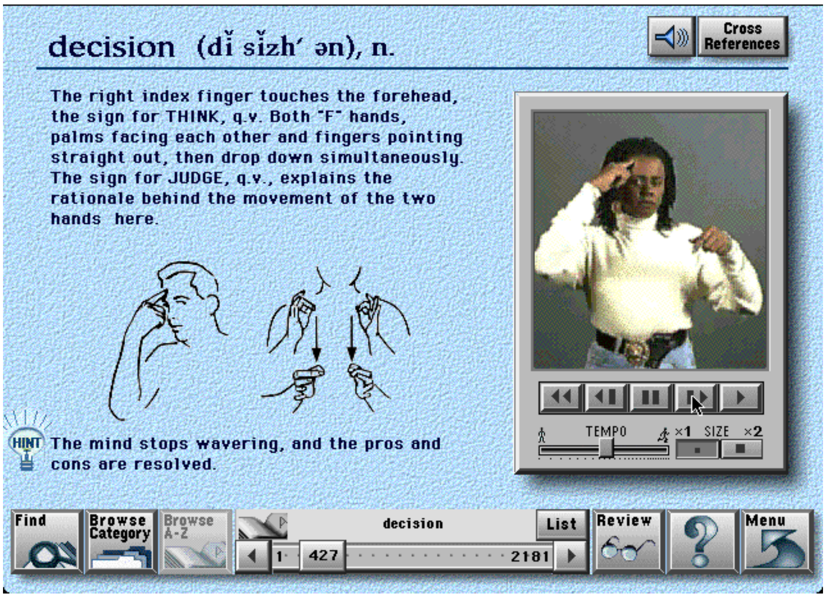
FIG. 43
Menu of the ASL Dictionary

Let us now look at the ASL Dictionary by way of comparison. It opens on a page with five large buttons, called »Main Menu« by the designers, which invite the users to choose one of five modes of the dictionary in which they would like to work. The five modes of the dictionary are the dictionary itself, a training section (Skills), a practice program for fingerspelling, an overview of ASL, and finally a »Guided Tour«, an animated tour through the program.

Even if we ignore the functions »Fingerspelling«, »ASL Overview« and »Guided Tour« for now as not relevant to a comparison (on the CD-ROM for the Dictionary of Computer Terms, there is a practice program for fingerspelling as well, the Guided Tour is an animated online help which has been realized in a different manner in the *Dictionary of Computer Terms*, see below), we can already recognize a basic difference: Two functions remain, »Dictionary« and »Skills«. The *ASL Dictionary* apparently has an educational function, it offers a separate section on »Skill« training. I will come back to this later on.

If one selects »Dictionary«, the next screen appears in the ASL Dictionary:

FIG. 44
The Dictionary Section in the ASL Dictionary



The dictionary entry in the *ASL Dictionary* looks completely different: there is no definition of the term, instead, it is accompanied by the description of a sign. To the right of the screen, a film of the sign appears in a kind of simulated video player. The sign is played immediately, while at the same time a speaker reads out the description of the sign. Beneath the text with the sign description, there is a static schematic drawing of the sign and a pointer to its interpretation. The bottom of the screen offers various functions for selecting other terms: a slide control for selecting one of more than 2,000 signs, and several term lists.

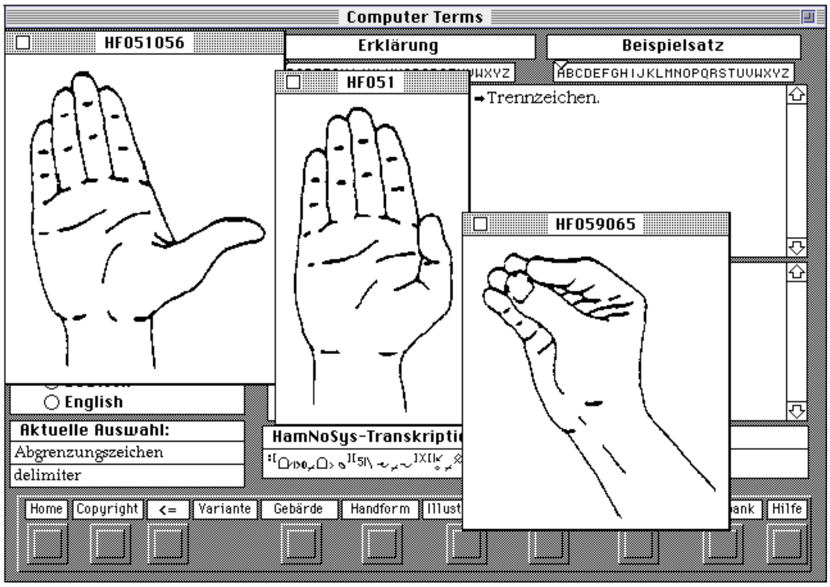
The difference between the two dictionaries is obvious: The *Dictionary of Computer Terms* deals with a specific terminology and must thus contain a traditional dictionary section. The *ASL Dictionary* deals with everyday terms which do not need to be explained. The text of the dictionary that is read out offers redundant information on the film, as does the schematic drawing. The design may be interpreted as an attempt to realize something in the manner of the Dual Coding Theory [Paivio (1986)], which states that redundant information on multiple channels leads to a better embodiment of that information in the memory.

The *Dictionary of Computer Terms* reaches this level of functionality if one of the buttons at the bottom of the window is selected: »Gebärde« [Sign], »Handform« [Hand Shape], or »Illustration«. If one selects the »Gebärde« button, the sign appears in a window of its own, which also has a control bar that allows a manipulation of the film as in a video player:

FIG. 45
The Sign Film Clip in the *Dictionary of Computer Terms*

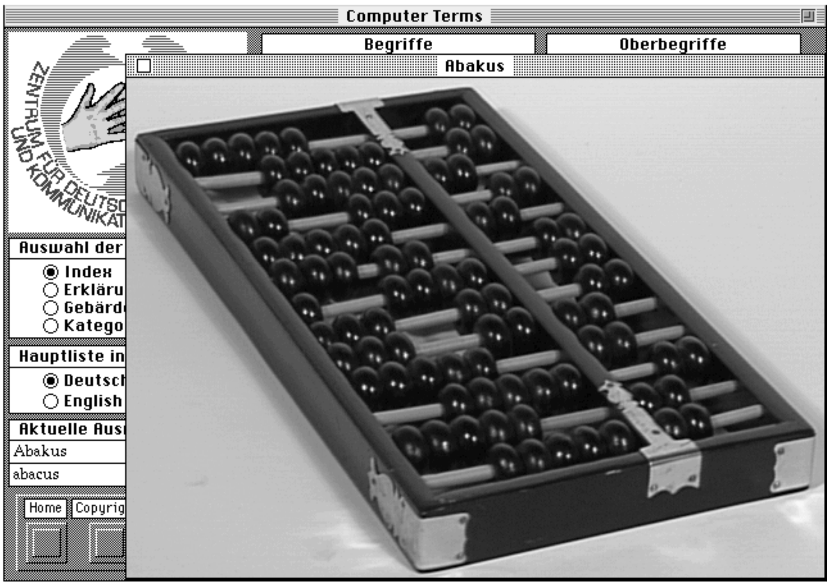
If one clicks »Handform«, up to five windows with illustrations of the hand shapes occurring in the sign appear:

FIG. 46
Hand Shapes for the Sign



If one clicks »Illustration«, a window with an illustration (photograph, diagram, animation, or film) of the currently selected term appears.

FIG. 47
Illustration for the Term (here: Abacus)



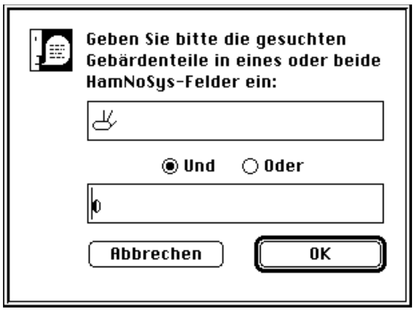
This varying of information is also intended to fulfil the educational task of utilizing several channels for the coding of the information, only that in this case the different media are not redundant.

Differences in the Design of the Two Dictionaries

Special Dictionary Function: Bidirectional Search Options

The *Dictionary of Computer Terms* offers a special function that allows searching for signs without having to make a detour through the verbal language entries. To this purpose, all signs in the dictionary have been transcribed with the notation font HamNoSys (Hamburg Notation System) [Prillwitz/Zienert (1990)]. If one selects the function »Finde Gebärde« [Find Sign], a dialogue appears, in which one may enter up to two search strings coded in HamNoSys that are linked with »and« or »or«. One can thus search for signs using a particular hand shape, making a particular movement, executed in a particular location, touching a certain part of the body etc., and for combinations of those features.

FIG. 48
Dialog for Finding Signs



The result is a list with all transcriptions of signs that correspond to the search criteria. In the left column of the list, there are the dictionary entries, in the right columns the HamNoSys transcriptions of the corresponding signs. Depending on the search criteria, the list will contain some hundreds of signs, or just a few. The user may select any entry in the list, and thus call up a certain sign directly from the list:

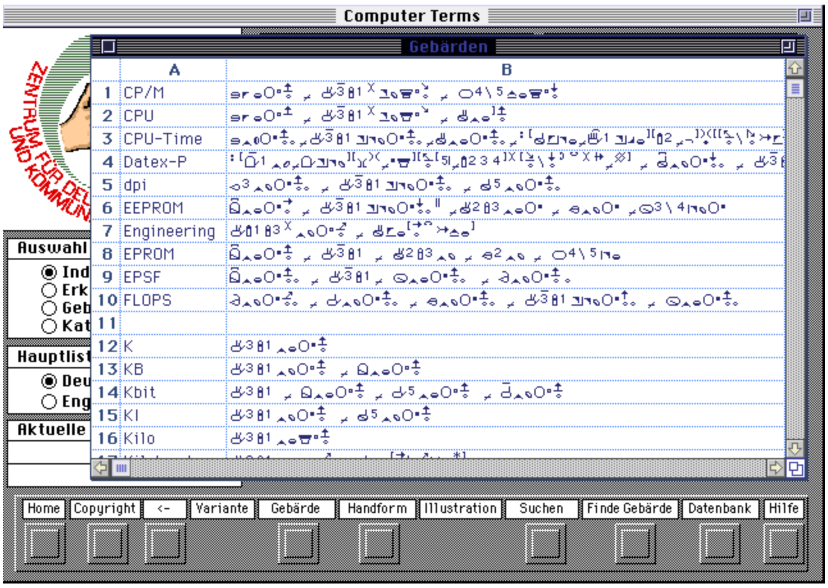
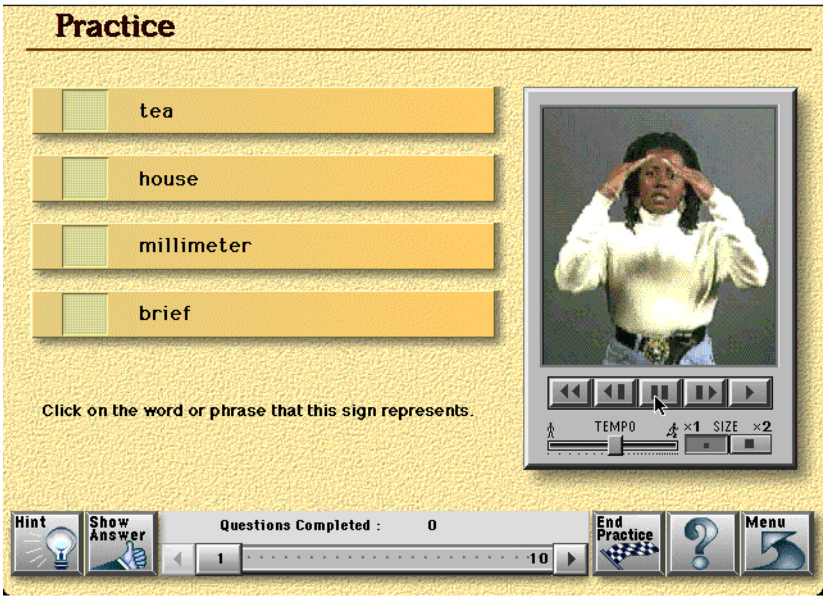


FIG. 49
Result of a Search for Signs

The search for signs in the *Dictionary of Computer Terms* was a first step for us in 1993 of realizing a bidirectionality of signs and written language in a sign language dictionary. With this part of the program, the *Dictionary of Computer Terms* for the first time has realized for sign languages a typical function of dictionaries in two languages. Notation in HamNoSys, developed by the Institute for Sign Language and Communication of the Deaf at Hamburg University, was chosen as a link between written language and signs because it allows a very precise description of signs. Search options are much more varied in this way than if only a search for some few components of the sign was admitted. Finnish colleagues have developed a dictionary of basic signs in Finnish Sign Language, in which they have implemented a search for signs of a certain type through making a selection from a limited number of static pictures. Such a type of searching in clusters of sign features has been realized by the Project Team Technical Sign Dictionaries at the Institute for German Sign Language at Hamburg University [s. Konrad/Kollien (1996) and Hanke (1997)] with the *Sign Language Dictionary on Psychological Terms* in the World Wide Web [URL http://www.sign-lang.uni-hamburg.de]. Future versions of electronic sign dictionaries will offer the option to »hide« transcription and search for signs directly out of the video.

FIG. 50
Exercise Section in the *ASL Dictionary*



Instructional Function: Skill Training and Competence Test

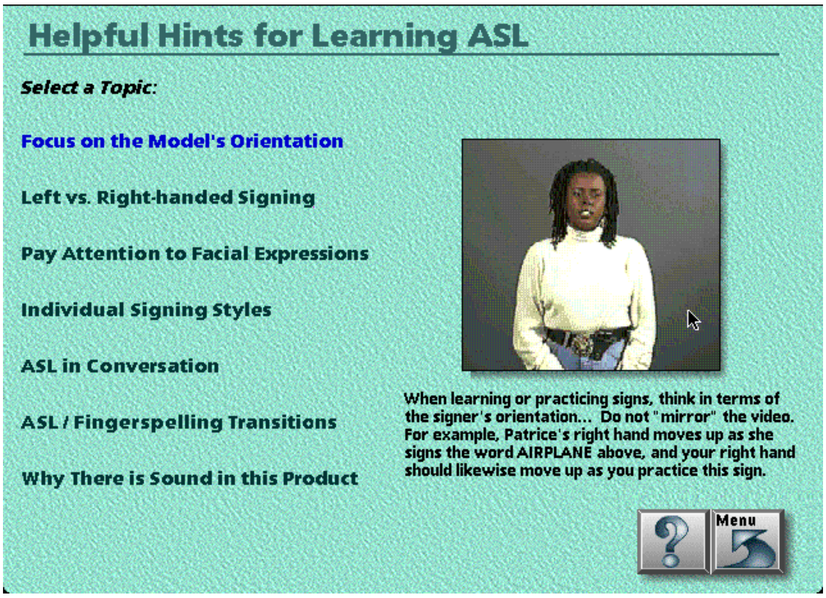
The practice part in the *ASL Dictionary* presents, depending on the learner's choice, a limited set of signs chosen by a random generator, the signs that were looked at in the current session, or all signs in the dictionary. Next to the sign, there appear possible corresponding terms from spoken language which can be assigned to the sign in the form of a multiple choice test. The program calculates and memorizes the success rate.

The practice part of the *ASL Dictionary* also contains other exercises, e.g. pairing sign and spoken language term in a kind of Memory game. It becomes clear from these exercises that the ASL Dictionary, other than the Dictionary of Computer Terms pursues an educational aim, a »skill training«. (I do not want to discuss the suitability of the methods employed here.) The American dictionary wants to be a training program for everyday signs, which do not need to be explained, while the German dictionary wants to be a dictionary for technical terms in the first place, and thus neglects the question of how the users could learn and retain those signs more successfully. This difference in interest and orientation of the two dictionaries' developers is responsible for the different design of the applications.

Navigation: KIOSK versus Window Interface

The ASL Dictionary uses the principle of »presentation frames«, as they are called in instructional design, and which in this context are perhaps best called »pages«. Each of the five subdivisions in the ASL Dictionary has its own page design. There are also some additional pages that serve as connecting areas and offer tables of contents with branching options. The next illustration shows the page for the »Hints for ASL«. The page remains the same all the time while the user works off the options on the left-hand side.

FIG. 51 Special Advice on ASL in the ASL Dictionary



Such a design concept, which works with a limited number of fixed pages, is called a Kiosk system (s. Ch. 9), because the choice options are presented here as in a kiosk in a well-ordered display. Kiosk systems are supposed to make it easier for the user to navigate a system with several choice options and navigation possibilities by simplifying the user interface.

The *Dictionary of Computer Terms* on the other hand only presents a single page, only one »frame« to the user, and thus reduces any problems the user might have in navigating. Instead, the various modes which the program offers to the user (sign films, illustrations, texts, hand shapes, lists), appear in separate windows on top of this page. The program ensures that open windows are closed if the user switches to another mode.

Online Help

Both programs offer online help. The *ASL Dictionary* uses an animation for this purpose, which shows the user how to use the program. The authors call this form of help a »Guided Tour«. The classification as guided tour is not quite correct, strictly speaking, because the user cannot do anything in this animated demonstration. The term guided tour is by rights reserved to systems that guide the user as in a tour, but let them take the steps on their own. This animation plays automatically, like a film. Animation is a nice form of help, especially for beginners. Experienced users of computer programs will always abort such an animation, because passive watching costs a lot of time, and one cannot skip the passages that one is familiar with.

The *Dictionary of Computer Terms* uses balloons which can be switched on or off as online help: In order to get help, the user must point the cursor directly on the object for which he needs help. A balloon with a help text will then appear above the selected object. This is certainly not as lively and not as much fun as the animation, but this method can give specific help and save time for the user.

Conclusion

I have compared some features of two sign language dictionaries: function and design. The design of both dictionaries is conspicuously different. The dictionary for technical terminology is basically a hypertext system with multimedia additions. The *ASL Dictionary* is a multimedia Kiosk system. The connection of design decisions with the respective intended functionality has become clear: one dictionary offers technical signs and texts with technical terminology and illustrations, the other everyday signs, exercises, and practice methods. One could ask of the one whether it should not have had practice sections as well, which would make it easier for the user to learn the signs effectively. With the other, one could discuss whether it shouldn't have had illustrations and other texts than the redundant descriptions of signs.

But perhaps it has also become quietly clear to the reader through these descriptions what immense advantages electronic dictionaries can have for learners of sign language, quite independent of their concrete design: quick selection of terms, cross-referenced texts, direct access to individual signs, a rich repertoire of multimedia information, comfortable practice options.

With *HyperLexicon*, Bui (1989) presents a dictionary for vocabulary practice based on hypertext which realizes conceptual relations like hyponymy, metonymy, and antonymy. One can create relations between the terms in the dictionary, like e.g. »x is a y« (hierarchical classification), »x is a part of y«, »x is related to y«, »x is similar to y«, »x is to a what y is to b«, »apply x to y«. These relations go far beyond definitions, which are also contained, and can be represented in the form of tree diagrams and through parametrized semantic scatter plots. Text, image, and sound are linked to each other.

The representation of a bilingual, English-Portuguese dictionary in Harland (1992), however, seems a hybrid self-interpretation to me. The dictionary with language exercises, which is surely passable, may be suited to flexible, self-paced learning, but it does not represent the form of hyper-model for non-linear learning as which the author presents it.

The »Istituto Italiano per gli Studi Filosofici«'s multimedia encyclopaedia for philosophy [Parascandalo (1992)] is to include excerpts from more than 400 interviews with well-known philosophers, thousands of pictures, and more than 100 hours of video.

Design Guidelines for Electronic Books

Electronic books can be said, rather than normal hypertexts, to have the regular document structure approximately described in the guidelines of Office Document Architecture (ODA, ISO 8613, 1988) [Brown/Cole (1991)]. Richards (1991) discusses document design for the page structure of electronic books by way of three different examples: the screen layout of a learning program, a draft for an interactive travel guide, and the planning of hypermedia books for handicapped people. Glushko (1989), who reports that the transformation of the Engineering Data Compendium's four volumes with their 3.000 pages and 2000 illustrations and tables into hypertext cost roughly $250.000, with the major part of that sum going into analysing the user-oriented concept and designing the corresponding user interfaces (297), names five principles for the design of electronic encyclopaedias.

Research into active reading in electronic books may be important for the further development of the underlying concept. In doing this research, one should not repeat the fault of previous evaluations of letting the phenomena to be studied be influenced too much by parameters of only temporary value. Functions of active reading that should be researched are marking, underlining, annotating, making extracts, skimming, structuring, creating indexes, index search, searching with filters, focusing, sequencing. Some of these reading functions have been studied by De Diana (1991) by way of the example of electronic books.

The design of electronic books is still too much an imitation of real books. The designers are apparently trying to exploit the book readers' familiarity with the traditional medium, in order not to let the divide between books and electronic books become too wide. But as soon as a higher degree of familiarity can be assumed, one should think hard about original structures for electronic books, in order to present the digital versions' functional advantages more clearly. What we lack in this context is indeed a kind of »rhetoric« or »semiotics« of this new medium, which not only takes into account that one can access each text in a fraction of the time, connect any text with any other, and instantaneously search for and locate any text passage, but also that some day it will be possible to dynamically generate whole argument sequences in text, to extract automatic abstracts and content analyses of texts, etc.

Barker (1992b) distinguishes three kinds of design guidelines for electronic books (84ff.), according to the respective dominant paradigm on which they are based: how the medium is employed (hypermedia, reactive medium, surrogate), the kind of learner control that is aimed at, and the intended use (as learning program or application program). Barker cites design guidelines for all theses cases, but it would be going too far to cite them here.

Cook (1988) describes various prototypes for Grolier's *Academic American Encyclopedia*, from a text-only version to the multimedia version; Marchionini and Shneiderman (1988) use Grolier's *Academic American Encyclopedia* as their example to present a special searching method, which they contrast with browsing; searching vs. browsing is also studied in Qiu (1993a). A simple, but effective example for the effect of a minimal modification of screen design is illustrated in Hodges and Sasnett [(1993), 43].

Discussion

There seems to be no better alternative to electronic children's books (e.g. by Brøderbund). They offer the following options: watch animations, have the book read out aloud, prompt some elements in the picture into action. In multilanguage versions, the language can be selected. With some books, the animation is partly changed for each session, which heightens the children's suspense in repeated reading.

Electronic books are widespread and very handy as online help. Thus many programs today possess a hypertext help in book form, in which the user can look up almost all user problems. The advantage that online help has over electronic books is that one will hardly read the entire book in its electronic form, but only look up the questions which one wants answered at any given time. Online help may however already have been outdated by the next stage of development, when passive help books are replaced by active help systems. Thus Apple's new help (»Apple Guide«) quite literally demonstrates to the users what they should do to solve their problem, e.g. select a command from the menu or tick an option in a certain dialogue, by drawing a red circle around the respective area on the screen. If the user does not execute the suggested action, the help program even takes matters into its own hands and executes the action on its own, which it then politely reports to the user, without any irony or criticism.

Electronic books may be particularly suitable for textbooks, for a special reason: the CD-ROM medium is cheaper than traditional book production, it allows a quick succession of updated issues, and is more ecological, i.e. there is no wastage of paper. Another fact speaking in favour of electronic books is that, for reasons of cost and space, one can hardly present as much visual information as in electronic books, although this aim can be also be achieved with multimedia databases and encyclopaedia-like multimedia applications. Apart from that, there are many arguments against having to work through a book exclusively on the screen.

Textbooks are however fraught with a special problem that will probably continue to obstruct mass production of electronic textbooks for a while: Who is the expert, then, for a particular field, which are the experts whose knowledge is to be incorporated into the textbook? This question is also put by Duffy and Knuth (1990): »Is the project specific to a particular instructor's viewpoint? Would other faculty be willing to use this individual's representation?« Many university teachers reject most standard textbooks, or prefer another one than the one commonly used in introductory courses – what they would really like to do is write their own textbook. This fate might also be in store for electronic textbooks. But there are two ways out of this problematic situation: For one thing, it is economically feasible to produce many competing electronic books because of the low cost. And for another, the hypertext structure encourages a combination of many different texts by different experts, and the storage space available on CDs allows bringing many authors into the production and having them write pluralistic textbooks.

There are no universal experts; therefore I have no choice but to present as many experts as possible (as in Perseus). If one succeeded in integrating a variety of views into electronic books, to present as many and meaningfully varied viewpoints of different experts as possible and offer them for comparison, then this could abolish the disadvantage of traditional textbooks written by one or a limited number of persons: »if we wanted a generalizable product, then we would have to be sure that other instructors in the domain would buy into that construction as well« [Duffy/Knuth (1990)].

CHAPTER 9

The Electronic Bazaar

Kiosk Systems and Guided Tours: Definition

KIOSK systems[26] are online presentations with controlled author-edited paths, or hypertexts with prefabricated links [Jonassen/Grabinger (1990), 7]. The basic concept of Kiosk systems is »animated page-turning«, the page-turning machine. The typical application is the so-called »point of information« (POI) or »point of sales« (POS), applications for marketing purposes which the visitor in shops, department stores, at fairs, train stations or the airport can operate unassisted. Such applications will be the future methodical basis for »Tele-Shopping« [Riehm/Wingert (1995), 58ff] and interactive television, which the Time/Warner group is currently testing in Florida in the large-scale experiment »Full Service Network« (84ff). Among the first examples in Germany are the OTTO [a mail order house] catalogue on CD-ROM and the »InfoThek, Das kostenlose Stadtinformationssystem« [Free City Information System] of the city of Bremen, produced by the University of Bremen.

An extension of Kiosk systems in the direction of hypertext seems to be possible [Kuhlen (1991), 150ff]. On the other hand, one might also consider the reduction of a hypertext to a Kiosk system, or even a simple presentation, through a strict limitation of navigation possibilities. But on the whole Kiosk systems rather follow a narrative chronology than a hypertext form of narrative [Bolter (1993)].

Kiosk systems can also supply the interface for multimedia databases. Databases have played an inferior role in science up to now, because the collected traditional knowledge of each field has mostly been preserved in other forms and can hardly be put into a database in its entirety. Although it would of course mean immense improvement if the data which have been collected in inaccessible places (slides in medicine, biology, archaeology, history of art etc.) could be consulted in accessible form (random access, index, PhotoCD). In a next step the image databases could then be combined with learning systems, in a Kiosk, a free hypertext, or electronic textbooks.

26. The title of this chapter is taken from the title of the essay by Bolter (1993).

Databases are neutral in their application. They can supply the basis of both authoring systems and hypertext systems. Quite original applications may result from this. Thus Degl'Innocenti and Ferraris (1988) introduce *Datamondo*, for example, a journal database that can be used for teaching arts or social sciences. Increasingly, special solutions for individual fields of science are on offer: *Chronos* (Imaja), for example, is a database designed for history with editable timelines (several formats for 60.000 years are provided) and commentaries which can integrate illustrations and sound. Picture windows, lists, maps, and keywords help to organize the information. The distribution that image databases have found in biology is hardly surprising. The whole series of CDs with animal species published by Sumeria is one example.

Kiosk systems are today primarily employed in the multimedia presentation of trade fairs, mail order catalogues, exhibitions, museums. Many CD-I programs are based on this concept. One major drawback of the presentation of Kiosk systems, especially if displayed in public areas, is that one can only assume relatively short times of use (10-15 min) [Wilson (1992), 192]. The number of branches in such systems is low (a frequent maximum is 5), the number of hierarchically practicable levels is even lower (mostly 3). One can imagine an application of the Kiosk format in science, but the strict limits of the Kiosk will often have to be exceeded. This can already be observed in some applications that simulate virtual museums.

Presentations

The most simple variation of the Kiosk system is the presentation. Multimedia presentations are not very widely used yet, because most presenters do not yet have access to the necessary technology. But it is foreseeable that this method will quickly spread at trade fairs, conferences, marketing shows, and presentations in firms. Lennon and Maurer (1994) have studied lecturing methods of the past (blackboards, flip charts, daylight projectors), and discuss –10 years too late, actually – how theses methods might be realized on a computer. The method of presentations resembles putting transparencies on a daylight projector. Few presentation programs allow free browsing, which would be better suited to free speech; most of them have a fixed order of screens and thus force the lecturer into a pre-planned course of argument. !Forbes has brought a CD-ROM with a »Presentation Trainer« on the market, a course for presentations which is itself designed as a presentation. The CD offers a rich collection of design guidelines for presentations [s.a. Chabay/Sherwood (1992)].

FIG. 52
Introduction to a Chapter in the !Forbes »Presentation Trainer«

At the bottom of the screen appears the chapter structure: *Intro/Help*, *Logic*, *Graphics*, *Presentation*, *Gallery*, and *Index*. The contents of the current chapter appear in the box in the left margin of the screen: In the top illustration, the table of contents for the introduction, in the bottom picture, the contents of the chapter »Logic«.

FIG. 53
Diagram 'Communication' in the !Forbes »Presentation Trainer«

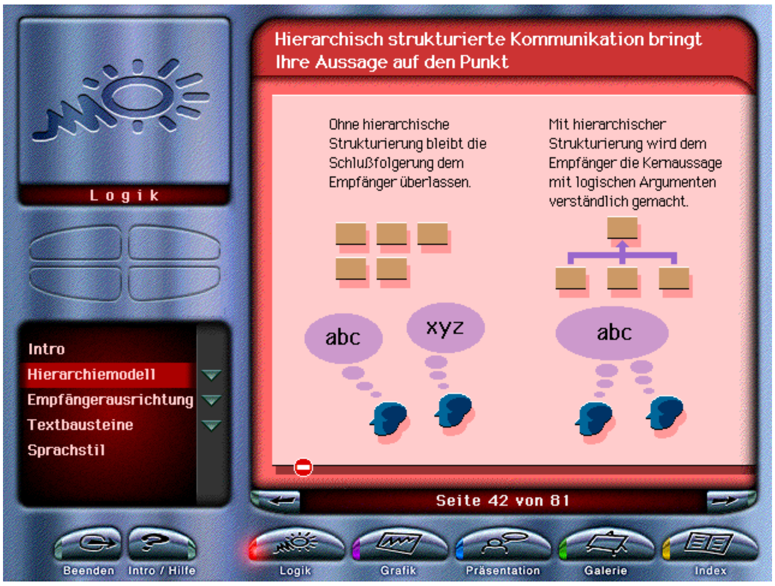


FIG. 54
Matrix for Choice of Media in the !Forbes »Presentation Trainer«

Branches in the »Presentation Trainer« are – as in presentations – only one layer deep. In the above illustration, there are branches to explanations of the media which are illustrated in the matrix, and, top left above the table of contents, to an animation and further information.

Guided Tour

Hypertexts with fixed navigation paths are also called Guided Tours if they follow the »surrogate travel« metaphor in their design. The term Guided Tour was apparently coined by Trigg (1988) [s.a. Gloor (1990), 145ff]. The Guided Tour employs the method of self-contained episodes: From the end of an episode, there is only a way back to the start, no cross-entry into other episodes. The hypertext structure is that of a tree, not that of a network. The number of branches and levels can however be much higher than with Kiosk systems. And the time of use may also be assumed to be higher.

The Guided Tour can be characterized as a network variant despite the restriction to pre-planned paths. Stotts and Furuta (1989) describe the Guided Tour as a subset of hypertext: »A Guided Tour is formed from a pool of possible display windows (‘cards’). The various cards of interest to an author are collected into sets called ‘tabletops’« (17). A tabletop in its turn is a Petri network fragment with only one transition, which is connected to as many other locations as there are tabletops (minus the first one). One must imagine these as partial views of the tour, which in their turn are made up of hypertext nodes [Trigg

(1988)]. Trigg has realized the examples for his reflections as a pure text system in *NoteCards*. In hypermedia environments, such concepts are more sensibly employed in a graphical manner.

Paths can also be constructed dynamically in a Guided Tour, for example depending on user interests or learning prerequisites which must be polled. Such an example, which makes a database with data on university courses and dynamically calculated paths accessible by way of retrieval technology, and uses the travel metaphor in doing this, is discussed in Guinan and Smeaton (1992). A graphical user interface is indispensable for a Guided Tour, they must be absolutely self-explanatory. Guided tours are constructed with the means of hypertext systems, but they can be developed in other ways, e.g. with authoring animation software like *Macromedia Director*. Control over content and navigation is given back to the author in Guided Tours, while the user can only follow the pre-set paths. It may be for this reason that many authors treat the Guided Tour only as a navigation method in hypertext, and not as a software genre of its own [e.g. Guinan/Smeaton (1992); Nielsen (1995)]. The concept of the Guided Tour can also appear as chronology, i.e. in the form of an arrangement in which the tour stops are lined up chronologically, as in a timeline. This is the case, for example, for the laser disc on van Gogh (Voyager Company), which structures all stops by way of the painter's biography, or the CD »From Alice to Ocean«, one mode of which follows the author's travel route.

Some authors do not seem content with the restriction of navigation possibilities offered by Kiosk systems and Guided Tours in order to satisfy their need for controlling the learning process. For this reason, they employ the method of alternatively hiding the means of navigation and making them visible again. The intention is to facilitate navigation for the user, a method which makes sense for adventure games. Garzotto, Mainetti et al (1995) speak of »protected navigation« in such cases (11). Marshall and Irish (1989) have thought of another reason for sense and function of navigation restriction. They claim that Guided Tours and narrative structures make texts more understandable [cf. Trigg (1988)]. Such arguments strongly remind me of the topic I have already treated under the heading of »learner control versus program control«, and I would rather support Nielsen's (1995) argument in this regard: »Guided Tours are nice, but they really bring us back full circle to the sequential linear form of information. Even though Guided Tours provide the option of side trips, they cannot serve as the only navigation facility since the true purpose of hypertext is to provide an open exploratory information space for the user« (249).

There is no clear-cut dividing line between Kiosk systems and Guided Tours. Both systems present pre-fabricated links and only allow a relatively low degree of navigation to the user. The number of hierarchical levels for navigation and the path types can perhaps serve as distinguishing criteria. Kiosk systems typically have only up to three levels (contents, groups, individual objects), while Guided Tours may possess sequentially linked paths of unlimited length. But whether one calls e.g. a virtual museum with only two levels but a ring-shaped path a Kiosk system or a Guided Tour is probably rather a matter of taste. Neither can the presence or absence of a tour guide serve as a criterion, since even the titles of groups and objects in Kiosk systems could be interpreted as guides. The Encyclopedia of American History 1800 to 1850 [Oren/ Salomon et al (1990)] is such a blend of the two genres.

Digital Butlers, Tour Guides and Museum Guides

Some authors of Kiosk systems introduce historical figures as human narrators into their applications. The presenters have a historical dimension and personal characteristics.

Oren, Salomon et al (1990) choose historical figures as video guides, as human narrators, for their Kiosk system on American history. Guides are simplified agents, which serve primarily as navigation help, a tour guide, and which have a fixed (»canned«) content or function. The figures assume an individualized appearance through video technology, and in contrast to drawn, and thus typed, impersonal guides, also represent narrative contents. The authors suppose that it is the individualized appearance they have given to their figures which leads to the wish in users that the figures should also have an individual character: »If we had used a gold pan and a nugget to represent a miner or a covered wagon to represent a settler, it's doubtful that users would express the same desire for characterization« (373). Oren, Salomon et al believe that historical narrator figures are a good way of introducing something like personal opinions, and thus a pluralism of views, into the historical presentation: »Guides suggest a natural way to present multiple voices and points of view« (377). The narrators in Oren et al are no intelligent agents, but users automatically impute more intelligence to the characters than they possess. In a comparison of film history and four interactive laser disc applications, Plowman (1994) find parallels between the early days of film and the early stages of multimedia development. The figure of the explicator, according to Plowman, belongs to a stage in which the medium is still unfamiliar and the viewer needs help. Film was later on able to forego such figures thanks to technical improvements, but at this stage in the evolution of interactive multimedia programs, Plowman thinks it worth considering whether the role of the explicator should not be adapted for multimedia (289).

Bernstein (1990) envisions a blend of the impersonators in Oren et al and the human agents in Laurel (1990). He proposes a »clever apprentice«, a semi-intelligent program for the creation of hypertext links, a software agent that searches the hypertext and, supported by a knowledge base, offers suitable or possible links to the user. Since it is difficult to construct intelligent »link apprentices« and specifically reference them for the respective subject, Bernstein also proposes a »shallow apprentice«, which functions non-semantically. Littleford (1991), the author of HyperBase, a hypermedia system based on Prolog (Cogent Software Ltd.) with in-built expert system abilities, considers employing agents in hypertext systems, but does not think that the tools, expert systems and neuronal networks, are sufficient for supplying such functions.

Kearsley (1993) even sees agents as an alternative to intelligent tutoring systems. A tutorial program models the learners as a representation of their knowledge, while an agent models the entire personality of its user, it has a much wider task: »an agent must be capable of making a broad range of common-sense deductions about user goals and intentions« (299). In their answer to Kearsley, Dede and Newman (1993) point out, rightly in my opinion, that if this assumption were true, Kearsley's euphoria about the development of agents is somewhat out of place, because in that case it would be even more difficult to develop agents than to develop tutorial systems. Agents are not a superset of intelligent tutors, but are characterized by the very fact that they can take over small tasks and execute them efficiently. Indeed Kearsley seems to confuse the everyday knowledge (common-sense) the agent is supposed to master, and the breadth of the domain that is affected by this. That the agent's knowledge is on a common-sense level does not mean that the knowledge domain must be broader. On the contrary, agents are so effective precisely because they only model a small, but easily cognizable area of knowledge. Minsky has shown the way here with his »building blocks« theory of artificial intelligence: agents are like building bricks which can be stacked on top of one another. Complex tasks can be executed through a cooperation of agents without the individual agent having to be particularly complex.

The functions of an intelligent tutor and an intelligent agent are similar in principle, but the emphasis is different: An ITS aims at advising the learner, while agents are supposed to execute tasks given to them, they do not have any tutorial function, no »educational« mission, so to speak. This makes them much more sympathetic. It seems to me that Marvin Minsky's theory of smart agents is more suited to mastering larger tasks by a combination of autonomous units than an ITS would be. I suppose that future development will therefore go in this direction, quite apart from the fact that agents are more easy to program. While the educators still cling to the ITS model, artificial intelligence has long since jumped on the smart agents bandwagon.

KIOSK Systems and Guided Tours: Examples

Aspen Movie Map

The Aspen Movie Map was developed by Andrew Lippman at the M.I.T. in 1978. The present director of the M.I.T., Negroponte (1995), recounts the history of the development, the Israeli Entebbe commando unit, which was prepared for its mission with the help of simulations, and attributes the willingness of official authorities to support such simulations with sponsor money to this history. The Aspen Movie Map belongs to the type of »surrogate travel«, a journey through the city of Aspen in Colorado. Four cameras mounted on a car recorded each scene set at angles of 90˚ to each other, so that they could later be called from two laser discs in such a way as to simulate a three-dimensional illusion, a panoramic 360˚ view: »In 1978 the Aspen Project was magic. You could look out of your side window, stop in front of a building (like the police station), go inside, have a conversation with the police chief, dial in different seasons, see buildings as they were forty years before, get Guided Tours, helicopter over maps, turn the city into animation, join a bar scene, and leave a trail like Ariadne's thread to help you get back to where you started. Multimedia was born« [Negroponte (1995), 67]. Nielsen (1990) also calls the Aspen Movie Map presumably the first hypermedia application (38ff) [cf. Nielsen (1995), 40ff].

Palenque

Palenque is a DVI application on archaeology at the Bank Street College in New York, with a depiction of ancient Maya places of worship in Yucatan. The database consists of video films, photographs, sound documents, and text about the rain forest, the Maya, maps, and pictures of Maya hieroglyphs, whose exploration through the user is very close to discovery learning. The methods which Palenque offers to the user are, among others, an exploration mode with fictitious or virtual walks, a museum mode with thematically designed rooms on history, geography etc., fictitious experts on archaeology and museum guides, artificial tools like album, camera, and games. Palenque (like the Aspen Movie Map) had also already realized the 360˚panoramic view in videos which Apple is only just achieving with QuickTimeVR. It can be steered interactively with a joystick. The virtual walk can be directed through icons which call up tales, and initiate branching and zooms. Multimedia in Palenque does not renounce the traditional learning context. The system propagates the following educational principles: Child-Centered Learning, Direct Experience, 'Real World' Connections, Interaction, Analysis and Action, Engagement, Collaboration, Interdisciplinary Learning. These principles put Palenque in the vicinity of constructivist learning environments [Wilson (1988); illustrations in Luther (1988); s.a. Wilson (1992); s. Nielsen (1990), 68].

A tour through a nature reserve in England is offered on the ECODisk by the BBC, a CD-ROM developed with HyperCard [Nielsen (1990c); Nielsen (1995)]. Nielsen puts the ECODisk in the class of the Aspen Movie Map or Palenque (42ff).

FIG. 55
Lake and Forest Area in the ECODisk with Navigation Places

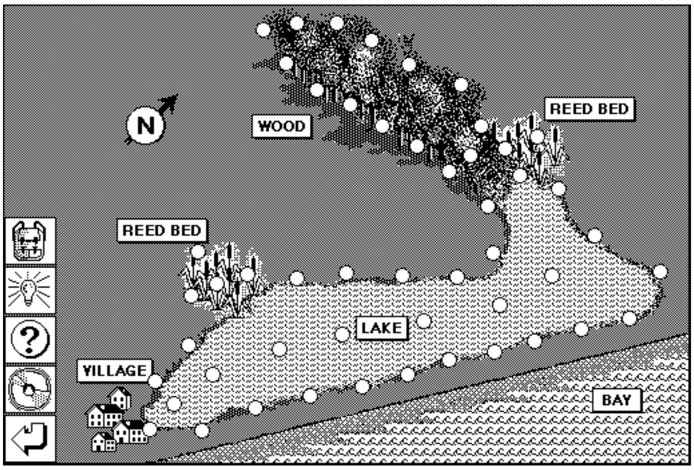
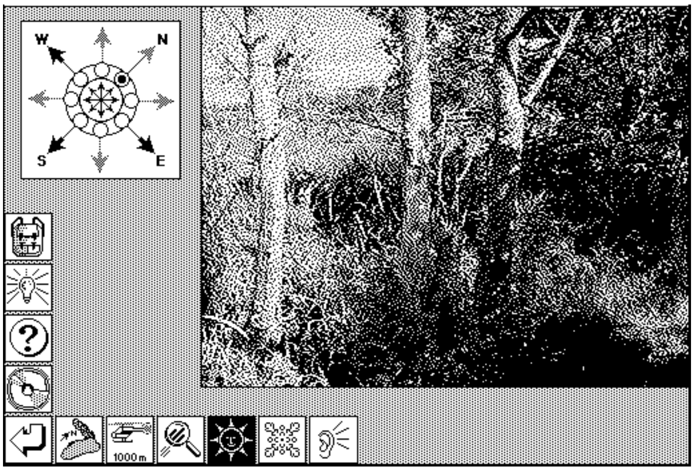


FIG. 56
ECODisk:
A Location in the Forest with a Compass for Panoramic Viewing



Bueno and Nelson (1993) describe a simple (in comparison to the Athena projects for foreign language teaching) version of a program that teaches Spanish by way of the »surrogate travel« concept.

A popular field for employing Kiosk systems are virtual museums:

One example of this is the Museum Education Consortium's project, coordinated by the Museum of Modern Art in New York [Wilson (1992)]. Taking part in this project are seven museums in the Eastern part of the United States. The system consists of a shared multimedia database with about 1000 paintings of the impressionists Cassatt, Cezanne, Monet, and Seurat, which are stored partly in analog format on a laser disc, and partly in digital format on hard discs, with texts, music, photographs, and video films.

Hoptman (1992) describes the concept of a virtual museum from the perspective of the Smithsonian Institute.

Dessipris et al (1993) describe an electronic interactive multimedia Kiosk developed with HyperCard, a guide through the museum of Dion (Greece), which presents information on archaeological exhibits.

Sterman and Allen (1991) report on several museum applications. A collection of electronic replicas of classical Greek vases in the J. Paul Getty Museum is described in some more detail.

Rees (1993) describes a Kiosk system developed with HyperCard on the sculptor Constantin Brancusi.

Chadwick (1992) reports on the employment of a multimedia program on the subject of »Domestic Water Consumption« in the New Mexico Museum of Natural History, and the high number of users.

Riehm and Wingert (1995) describe the hypermedia example of the »Ebstorf Map of the World« developed by the university of Lüneburg, which takes as its starting point a medieval map of the world hanging on the wall at the Museum for the Bishopric of Lüneburg, but which is also displayed on the screen, and from which information on 500 cities, 160 lakes, rivers, and seas, and 1300 texts can be called up (163ff).

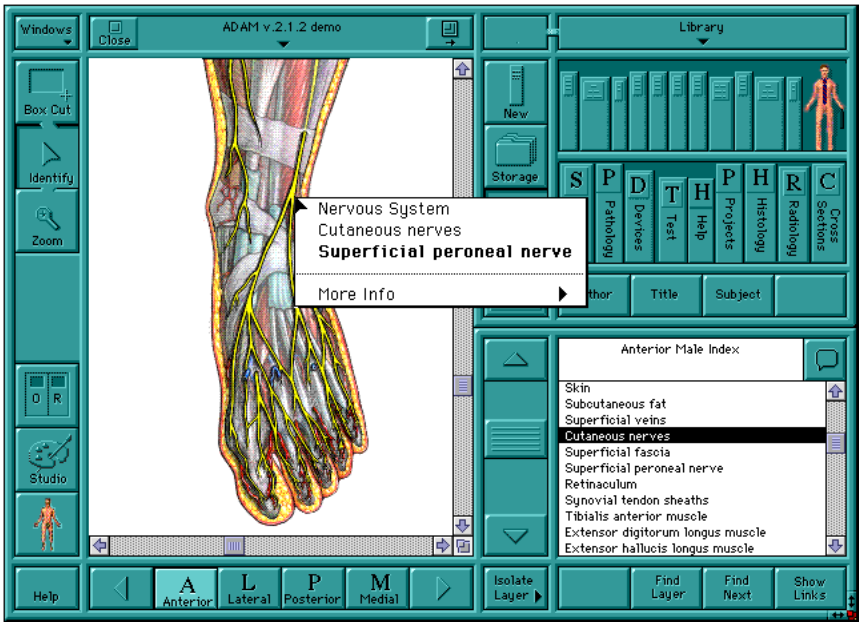
A museum of a special kind, a literary museum, is the »Bunkyo Museum of Literature« described by Saga (1991).

Bell (1993) describes the hypermedia simulation Sickle Cell Counselor, a Kiosk system standing in a museum that is supposed to advise visiting couples on whether they should have children if they have the sickle cell disease. Visitors can execute simulated laboratory tests and ask questions of the laser disc. The model is called »anchored instruction«, and claims to be close to the Cognitive Apprenticeship model. Further literature on museum applications will be found in Bearman (1991a) and Bearman (1991b).

The example of a Guided Tour which has probably become best known in literature on this field is Glasgow Online by the University of Strathclyde [Baird/Percival (1993)], a multimedia information system on the city of Glasgow, its institutions, public transport maps etc. [s. Hardman (1988)]. It is hardly surprising if a preferred subject of Guided Tours in the future will be travel guides, with the help of which one can plan ones trip or gather suggestions for a certain trip. A nice example of this is the CD »From Alice to Ocean« (1992, Magnum Design). Also designed to cause holiday fever are the CDs on far-off countries (e.g. »West Africa«) and »Ancient Cities« by Sumeria.

Other interesting future fields for employing Kiosk systems will probably be on-the-job-training in companies, library research, and games. Cantwell (1993) for example describes a Kiosk system of the Union Pacific company that is supposed to help improve the relations and morale of employees. The principle of the Guided Tour is also utilized in games, especially detective stories or mystery adventures. In »7th Guest«, the player enters a house in which he can move from room to room, and must solve a puzzle in each room.

FIG. 57
A.D.A.M.



The best-known example is A.D.A.M., in which the body can be uncovered layer by layer. A library offers literature on the currently selected parts of the body. A.D.A.M. allows the user to add to the atlas his own teaching sessions made up of texts, images, and films, as well as animations and new libraries with texts, images, and films. The program reaches such a high degree of complexity, however, that one must wonder whether this is still a Kiosk system.

The use of Kiosk systems also seems to be attractive for learning foreign languages. Some programs display Chinese and Japanese writing with the correct pronunciation, and demonstrate in animations the sequence of pen strokes necessary for the creation of the kanji. They offer mnemonic hints, and help with the learning of the many characters. KanjiMaster (HyperGlot) offers about 350 kanjis and 200 compounds with the digital sound of native speakers. The learner can choose his own tempo in learning. Mistakes are recorded and can be printed. In leafing mode, one can listen repeatedly to the pronunciation, study the kanji, read the English meaning, and practise the stroke sequence. »KanjiSama« (Sanbi Software) is a complete work of reference for advanced learners of Japanese with 2900 kanjis, 15000 compounds, two dictionaries, kanji reading texts, definitions, stroke counter, and cross references to other kanji dictionaries. »Welcome to Learning Chinese« (Huayuan Technology) offers an introduction into Chinese language with about 3000 characters. »Hanzi Assistant« (Dartmouth College) offers a basic store of 2500 Chinese characters.

FIG. 58
»Exotic Japan«:
Menu

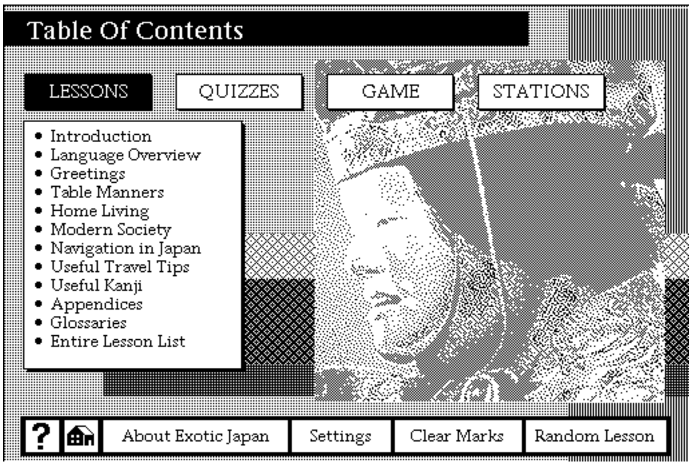
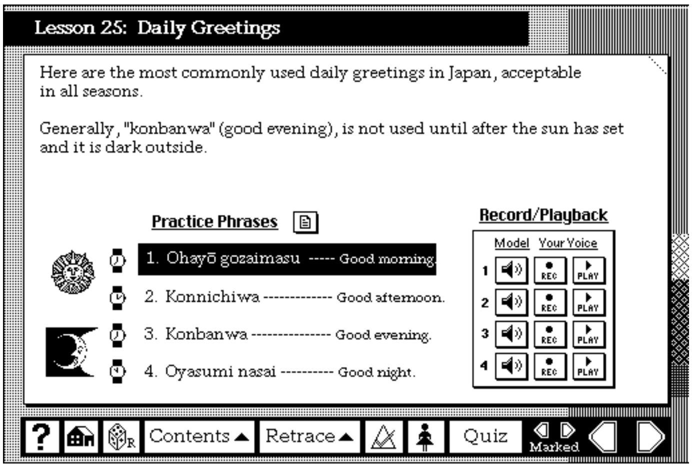


FIG. 59
»Exotic Japan«:
Language Exercise



The Drexel Disk, which the author calls an Electronic Guidebook [Hewett (1987)], is also a Kiosk system. After the Drexel University made proof of owning a personal computer compulsory for new students, the university provided a guidebook in order to make navigation easier for the students. From the guidebook, all central services of the computer service network can be called up by a simple mouse click. The master menu explains the user philosophy, the index provides hypertexts with help.

Another Kiosk system is Beethoven's Ninth Symphony, analysed musicologically with HyperCard (Robert Winter has since developed CD-ROMs on Mozart, Stravinsky and other composers following the same principle). The Kiosk knows four options:

- Beethoven's biography with integrated musical quotations.
- The analysis of the symphony and its musical structures.
- Finally, one can listen to the symphony while the previously read commentary runs along the screen parallel to the music.
- The listener can take part in a test in the end in order to test the knowledge that has been gained. The test also uses listening samples.

FIG. 60
Beethoven's Ninth Symphony: From the Biography

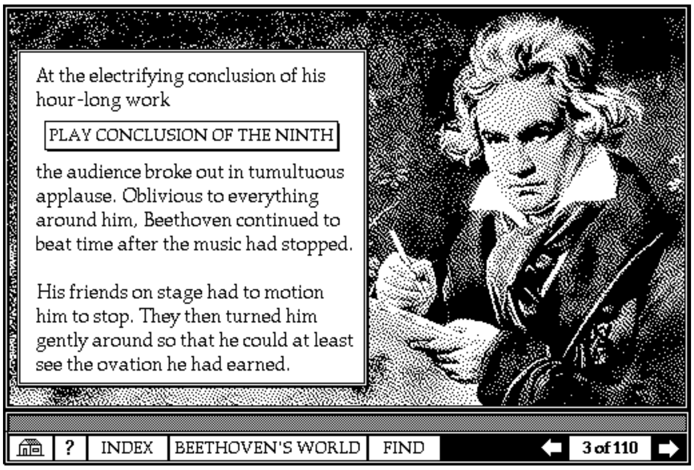
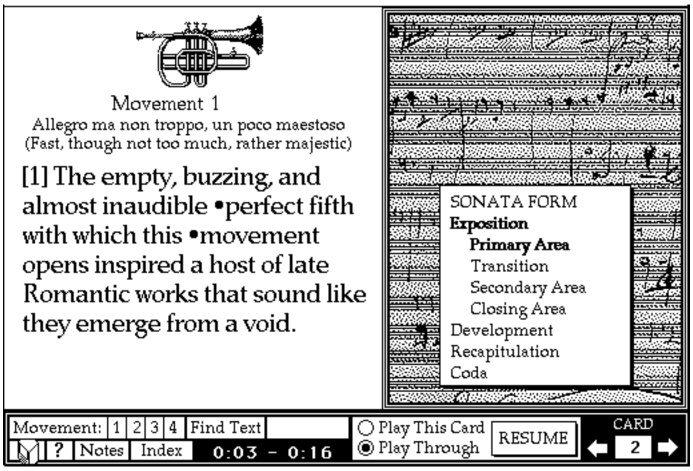


FIG. 61
Accompanying the Ninth Symphony with a Musical Commentary

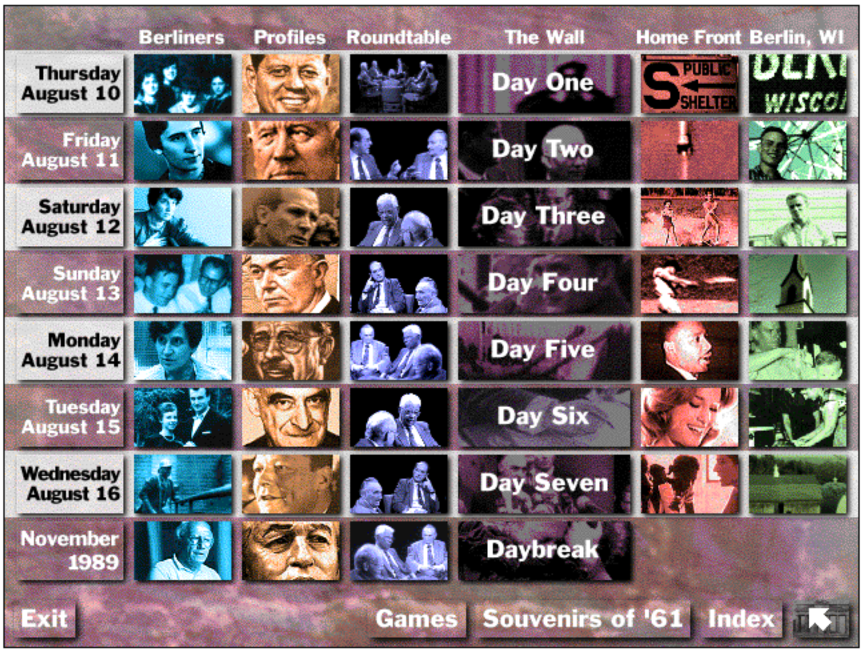


Set On Freedom is a hypermedia Kiosk on the American civil rights movement created with ToolBook [Swan (1994)], which accesses pictures and films from a laser disc. On the first level, there is a choice of People, Places, Events, and Viewpoints. The People section consists of biographies of 47 prominent personalities in the civil rights movement, which can be selected from a page with their pictures, the Places section describes 17 locations of civil rights activities, which are made accessible through a map of the USA, the Events section describes 54 events which can be selected from a timeline, the Viewpoints section can be explored from either a graphically designed or an alphabetical list of 12 topics. Cross references are offered in the texts and screens. A linear perusal of the material is not encouraged. Swan reports on changes in students' political attitudes, and concludes from their experience that »hypermedia applications can be designed in ways that support students' development of historical thinking« (136).

FIG. 62
First Page of
»7 Days in August«

»7 Days in August« (Time/Warner New Media) offers several kinds of information on the very first page: a tape recording of a television discussion, a Time article, an interview with a contemporary witness of the events, an excursion to Berlin, Wisconsin. This introduces the types of information which the CD offers. Somewhat inconspicuous at the bottom of the screen appear branches to the CD's two main structuring principles, a »Tour«, a Guided Tour, on the one hand, and a »Guidemap«, a Kiosk system menu, on the other. Both the structuring principles discussed in this chapter have been implemented on one CD.

FIG. 63
KIOSK Menu of
»7 Days in August«



The menu is typical of a Kiosk. It is structured in the form of a table or matrix. The matrix's vertical dimension consists of a timeline for the seven days of the events. The matrix's horizontal dimension is subdivided according to type of information: contemporary witnesses, personalities, excerpts from the television discussion, the progress of the building of the Berlin Wall, simultaneous events in Berlin, Wisconsin. With the »Games«, the »Souvenirs of '61« and the index, there are additional excursions branching from the Kiosk menu.

CHAPTER 10

Intellectual Aerobics

Interactive Cognitive Tools

Papert's Turtle microworld in LOGO [Papert (1980)] is mentioned over and over again as a paradigm for interactive programs that foster the learning of cognitive concepts. For years, working with programming languages like Smalltalk, called »Personal Dynamic Media« by Kay and Goldberg (1977), was considered the ultimate demonstration of the user's absolute control over program and machine. For a long time, there were no programs other than programming languages that allowed this form of learner and user control, with the possible exception of simulations, which however only in a few cases (e.g. STELLA, *ithink*) worked with direct manipulation methods. It is understandable if constructivists especially have high hopes in this paradigm, because it represents the pure embodiment of constructivism's message: not to separate learning and doing.

The first programs that allowed the generation and manipulation of objects through direct manipulation were developed in the field of graphics. I have coined the phrase for these programs, insofar as they are used for teaching, that they allow »learning by constructing« [Schulmeister (1989)]. Several authors of simulation programs use direct manipulation today, e.g. Moar, Spensley et al (1992) in a simulation model for horizontal movement, and Teodoro (1992) in a simulation model for laws of movement. What the learner constructs with these programs are not simply objects, but at the same time cognitive concepts, geometrical concepts, relations of objects and variables, depending on the current knowledge domain: »Constructivism is the psychological paradigm underlying most of these applications and instruction is conceived as a process in which the student constructs her/his own mental model of a given domain« [Midoro/Olimpo et al (1991), 180].

The technical basis of interactive multimedia tools is »direct manipulation« [Shneiderman (1983); Shneiderman (1986)]. Instead of command-oriented user interfaces, windows systems now prevail, with objects that can be grabbed, copied, duplicated, and transformed. Some programs already have features that reveal some »intelligence«, e.g. duplicating with offset in *MacDraw*, which »learns« from the user. Myers (1991) wants to strengthen such features in programs with his »Demonstrational Interfaces« for two reasons: to recover the programmability of sequences, and to simplify usability. Modern CAD programs can execute such mechanisms, as can geometry programs like Geometer's Sketchpad, to which I will come back in detail in the next section. Myers wants programs that learn from interaction, write macros on their own, draw conclusions, modify commands, and work out suggestions. He complains that the modern windows systems have made external programming impossible. But Apple Computer, for example, has achieved a programmable iconic user interface with *AppleScript*.

Brown (1985) has pointed out the role of cognitive tools in a keynote article. He already distinguishes tools that make the anatomy of an argument transparent, tools that facilitate understanding, and tools that support active reading and writing. He illustrates his wish for argument structuring tools with an anecdote that has since become reality with programs like *ThinkTank* (Living Videotext; successor MORE, Symantec), WEBSs, *SemNet*, and SEPIA:

> »After reading The Great Nuclear Debate [a difficult article from The New Republic, R.S.] we employed a research intern, Cece Blase, to analyze the article and attempt to cast it in a framework based on Toulmin's pattern. She eventually covered an entire wall with paper nodes and connectors. But the fascinating development was that as the anatomy of the arguments became clearer, she began to respond to the assumptions that were being made, questioning and challenging them. We could barely get her to finish 'diagnosing' the rest of the article« (192).

Brown hopes for a similar effect from cognitive tools as what happened to Cece with her wall notes, a facilitation of the step from analysis to construction: »If we can create tools to make an argument clear, perhaps we can involve more people in responding to it and developing it«.

Interactive tools for learning can be understood as »Cognitive Tools« [Kommers/Jonassen et al (1992)], with the help of which the learners can elaborate cognitive concepts on their own, with both intentional and incidental learning getting their share [Mayes (1992a), 9]. Kozma (1987) defines cognitive tools as »software programs that use the control capabilities of the computer to amplify, extend, or enhance human cognition« (21). They support the user in the cognitive components of certain tasks.

The conference proceedings edited by Kommers, Jonassen et al (1992) especially address the topic of cognitive tools. In the contributions of this volume the *StrathTutor* [Mayes (1992b)], *Learning Tool* [Kozma (1992)], *TextVision* [Kommers/de Vries (1992)], and *SemNet* [Fisher (1992)] are introduced as cognitive tools, among others. These tools are basically all variants of the outliner or sketch generator concept, a type of software that started with *ThinkTank* and found its continuation in MORE, a program that can translate outlines into flowcharts. *Design*/IDEF by Meta Software can construct and calculate Petri networks, and link them to hypertext. I have already pointed out elsewhere the importance of these tools for scientific creative processes of learning and writing [Schulmeister (1989), 56ff]. Reader and Hammond (1994) call these programs »mind tools« or »concept mapping tools«. Paquette (1991), too, views his rule-based expert system on physiotherapy as a tool for »knowledge construction« (148). Representational forms, such as problem-solving trees, can also be integrated into the constructivist approach (Reusser 1993).

TextVision-2

TextVision-2 is a tool that allows the representation of thoughts in the form of Concept Maps [de Vries and Kommers (1993)]. In this respect, it resembles the program *StorySpace* mentioned in chapter 7, which as a writing tool for hypertext systems allows the construction of arguments in the form of graphical networks with typed links.

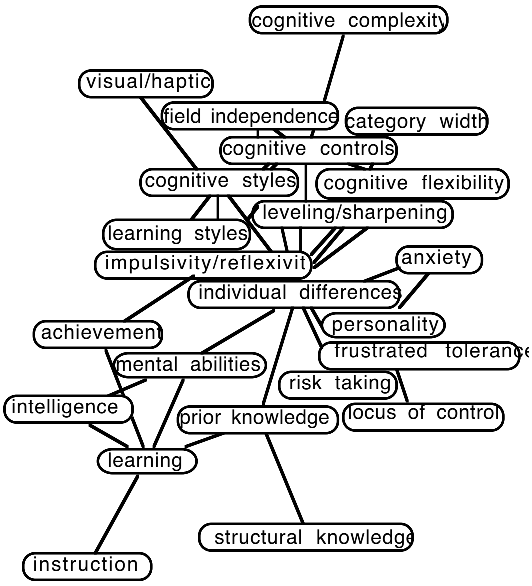
IdeaWeb

The Tool *IdeaWeb*, described by Ahern (1992), which allows computer mediated conferencing in *Hypercard*, resolves the construction of arguments by way of buttons, the relations between which can be represented as a network. *IdeaWeb* knows several ways of representation: maps of content relations (topic map), and maps of senders that have reacted to each other (neighbourhood map).

KNOT-Mac

KNOT-Mac is a knowledge network organizing tool for the Macintosh. It is employed in the study of Dunlap and Grabinger (1992) to generate graphical representations of knowledge from the interactions of the students.

FIG. 64
Expert Net after
Jonassen (1992e)

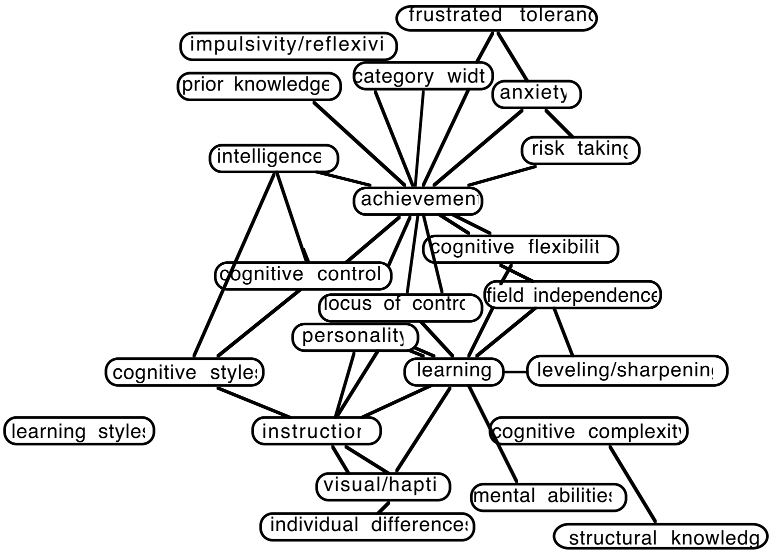


Pathfinder

Once one has generated knowledge representations, one can use *Pathfinder*. *Pathfinder* is a statistics tool for the analysis of cognitive maps [Jonassen (1992e), Schvanenveldt/

Durso et al (1989)].

FIG. 65
Studente Net after Jonassen (1992e)



Behavior Construction Kit

Resnick (1992) from the Papert group at the MIT describes the building and controlling of programmable Lego constructions, and calls this combination of Logo and Lego a *Behavior Construction Kit*. According to Resnick, the first generation of construction toys allows the construction of structures, the second the construction of mechanisms, and the third the construction of behaviour.

Cognitive tools integrate heuristic components into the learning process [Schulmeister (1989)], they allow a holistic approach to learning. That is, they allow a gradual approach to the larger cognitive concepts through explorative behaviour, the generation of concepts, and learning individual subconcepts only in the course of this process, while instructional systems favour an analytical approach. Instruction programs create tasks from subdivided learning objectives, start the reception of subskills with smaller skills and objectives, and then progress successively to the larger ones. Cognitive tools, according to Mayes (1992b), are completely different from intelligent tutoring systems: »This strongly suggests that the philosophy of intelligent tutoring is really orthogonal to the cognitive tool approach to learning« (13).

It is hardly surprising if constructivists are especially interested in cognitive tools, because they can be fitted almost seamlessly into constructivist learning environments – constructivism starts out from the premise, after all, that one must give learners the opportunity to generate their own concepts. Cognitive tools offer a chance for constructive action, with individual constructions playing an important part. Cognitive tools designed by constructivists – in some cases one can no longer speak of tools in the traditional sense, because they are already rather learning environments than tools integrating the entire learning environment– are mentioned in several places in the conference proceedings on constructivist learning environments edited by Duffy, Lowyck et al (1993): *Bubble Dialog* in McMahon and O'Neill (1993), the *Lab Design Project* in Honebein, Duffy et al (1993), the *STF Hypermedia Library* in Jones, Knuth et al (1993), *Round Table* in Knuth and Cunningham (1993), and *SemNet* in Allen and Hoffman (1993).

Round Table

Round Table by Knuth and Cunningham (1993) was developed at Indiana University. The tool is meant to support the explicit construction of cognitive concepts. The authors stress that the tool should not be looked at without its embedment in the social processes of studying, and that it can fulfil a meaningful function in this environment as a cooperative medium for working. *Round Table* supports the analysis of argumentations. It contains a number of case studies, in which the persons involved discuss and interact. The students' task is to identify the protagonists' conclusions, discover the line of argument, and the premises on which it is built. For this purpose, the students enter their discoveries for the respective analysed protagonist from the case study into the computer in three different windows (premises, line of argument, conclusions). All the other students can immediately afterwards see the arguments on their screens and comment on them. In the end, the students are supposed to apply this procedure to their own arguments as well. Apart from the case studies and the analyser, *Round Table* offers a number of tools which are meant to support students in this task: an e-mail component, a BrainStormer, group documents, and individual documents.

The active behaviour allowed by interactive programs helps to apply what has been learned and put it to practical use. Mayes (1992b), citing several other studies, speaks of an »enactment effect«, which can support retainment (11). Mayes qualifies, however, that cognitive tools only start at the point where already acquired abilities are reinforced. I do not think that such qualification is necessary. Cognitive, interactive tools can also be employed in discovery learning, they are also suited to supporting problem-solving and hypothesis formation [Glaser (1990)], i.e. to addressing the target areas which cognitivists call metacognition.

Salomon (1988) coins the interesting phrase that cognitive tools are something like 'AI in reverse', they are extensions of our cognitive abilities on the one hand, but can also be internalized through use. Only then do they become cognitive tools. Most of the respective programs possess a spatial representation with decision diagrams, flow charts etc. (129). Many authors express a hope that cognitive tools might be suited for fostering the creation of mental models [Resnick/Johnson (1988)]. Such opinions should be treated with care, however, because, due to a lack of other theories, the reference to mental models is always linked to a reference to the model of Gentner and Stevens (1983), which is committed to the symbol processing approach and closer to the objectivistic cognitive correspondence hypothesis than to constructivism.

Midoro, Olimpo et al (1991) call interactive programs ‘reactive’ programs, in order to make clear that the priority of action is the learner’s, and the program reacts to his actions. This usage is unfortunate, since the distinction between active and reactive has already been used for a different purpose by other authors. Thus many CBT applications are called reactive because they only react to user input. Among the types of programs that might be considered as cognitive tools according to Midoro and Olimpo are simulations, microworlds, and programming environments.

Interactive Multimedia Learning Programs

Learning Statistics with LearnSTATS

LearnSTATS [Schulmeister/Jacobs 1995] is a learning program on statistics which allows direct manipulation of statistical data, parameters, and concepts. It is intended as a learning environment for constructive and discovery learning. A similar program, but restricted to the problem of statistical random experiments and probabilities, is the program LOUTI by Bergeron and Bordier (1991).

Statistics for psychologists, social scientists and educationalists is mostly, even today, taught in lectures, with occasional accompanying exercises. Psychology students show a strong aversion to learning statistics, a motivational construct that has been identified as »fear of statistics« in a four-year-study[27] of learning processes [Schulmeister (1983)]. Most students of psychology have chosen this subject because they adhere to an ideal view of psychology as therapy and thus have little sympathy with empirical psychology. The project’s starting situation was characterized by the following basic data: only about 20% of the students learned statistics in the lectures, a further 40% had to do extra preparation for the exams at home or in additional study groups. About 40% of the students failed the exam.

E.L.M.A. was not only a research project, but a didactic intervention at the same time. E.L.M.A. defined a didactic concept which was based on the concept of discovery learning and consisted of a combination of working in seminars in small groups and feedback phases, accompanied by special study materials and lecture notes. The students’ cognitive learning processes were to be studied in the course of the intervention. Small groups in seminars replaced the

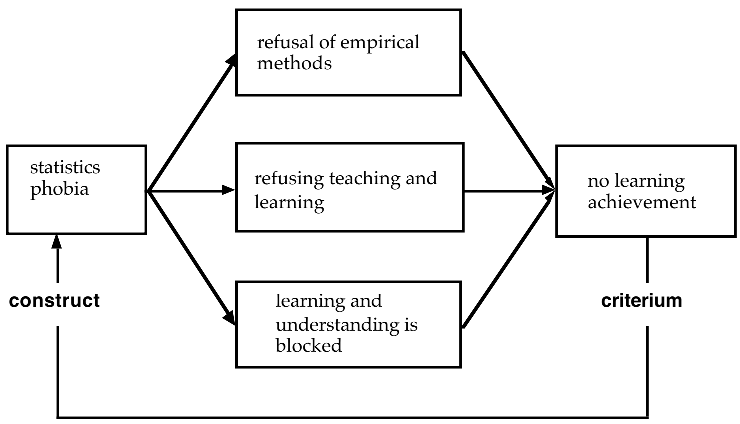
27. The E.L.M.A. research project (Evaluation von Lernprozessen in der Methoden-Ausbildung [evaluation of learning processes in methods education]) was supported by the Deutsche Forschungsgemeinschaft (DFG). Its aim was the study of cognitive problems of students in learning statistics.

lectures. The groups received printed materials with problem-solving exercises. There were feedback sessions at roughly 20 minute intervals. In these conditions, we evaluated the learning processes, conducted surveys, studied cognitive problems with the strategy of thinking aloud [Schulmeister/Birkhan (1983); Birkhan/Schulmeister (1983)], and continually improved the teaching materials by letting the students participate in working on the texts [Bogun/Erben/Schulmeister (1983a) and (1983b)]. As soon as the exercises were improved, the students learning success improved as well: about 60% of the students learned the basic facts directly in the seminars, 20% still had to prepare for the exams the hard way, outside of the seminars. Only 20% still did not make the grade.

The project was meant to make a contribution to the study of statistics phobia. »Statistics phobia«, or statistics anxiety, proved to be a combination of several related factors:

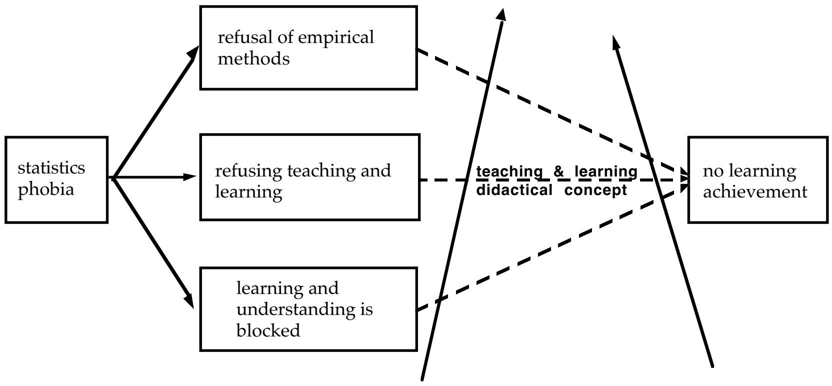
- lack of trust in empirical methods
- fear of figures
- aversion to systematic action
- discrepancy between humanistic motivation and the formal character of the methods.

FIG. 66
Construct of Statistics Phobia



Our hypothesis was that a different didactic concept might have a positive influence on learning success. The following illustration marks the suitable point for didactic intervention:

FIG. 67
Didactic Intervention



The two following tables illustrate the change in the distribution of the constructs »statistics phobia« and »statistics criticism« after three semesters:

TAB. 3
Statistics Phobia over a Course of Three Semesters

t	Aversion to Statistics	Neutral	No aversion
1. Term	73%	12%	15%
2. Term	25%	48%	27%
3. Term	31%	26%	53%

TAB. 4
Criticism of Statistics in the Course of Three Semesters

t	Critical of Statistics	Neutral	Not critical
1. Term	66%	6%	8%
2. Term	31%	42%	27%
3. Term	34%	13%	47%

The initially critical attitude gave way to an indifferent intermediate phase, and finally reached a bimodal stage. The correlation between emotional aversion and a critical attitude towards statistics as research method decreased in the course of three semesters from r = .71 to r = .39. The didactic concept of E.L.M.A. stressed four principles:

- establish a relation to psychology in both content and context in methods and statistics whenever possible, in order to appeal to the students' motivation

- design learning situations after the model of discovery learning whenever possible
- employ group work and feedback phases as often as possible.

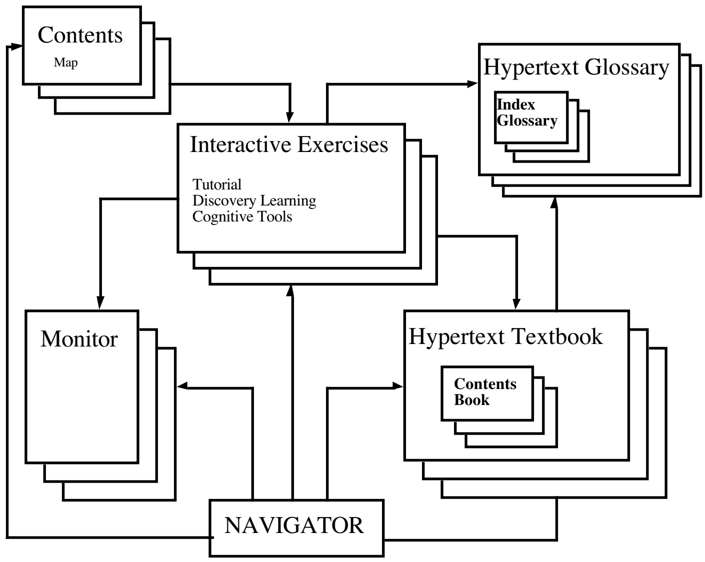
The exercises were developed by a team of psychologists. All faculty members involved in the experiment were prepared for the management group work and feedback phases in micro-teachings (teaching simulations). A few years ago, I found that the faculty members who had taken part in the project had either left the institute or turned to other teaching and research fields. Knowledge of the concept and the experience gained in the project and training sessions had been lost. I was faced with the choice of either starting from scratch again, or looking for a completely different approach to statistics learning. For this reason I started a few years ago to program the paper and pen exercises from the E.L.M.A. project [Bogun/Erben/Schulmeister (1983b)] on a computer. A hypermedia environment was chosen as authoring system, first *HyperCard*, later *SuperCard*, both of which have both hypertext functions and multimedia features, and possess their own programming language to boot. The object-oriented programming environment offered a number of advantages compared to traditionally structured programming languages: quick prototyping, flexibility of design, comfortable browsing, easy to use multimedia features, integration of external programs.

The Program Environment

LearnSTATS is not another statistics program, it is not a statistics program at all. LearnSTATS cannot be compared to commercial statistics software like SPSS or SYSTAT. LearnSTATS is a program for teaching and learning statistics in psychology, social sciences, medicine, and educational studies. LearnSTATS covers the entire current material of descriptive statistics: population, distribution, frequency distribution, statistical graphs, arithmetic mean, variance, standardization, parametric and non-parametric correlation, factor analysis, regression, multiple regression, and multiple correlation. For all of these topics, LearnSTATS offers a multitude of interactive exercises for discovering statistical concepts which are linked to a complete statistics textbook, a glossary, and an online help.

The exercises in LearnSTATS can in many cases not be compared to traditional statistical tasks and thus could not be executed with commercial software pakkages. Instead, they represent special didactic materials for tutorial experiments in a seminar or for self-study. Most exercises aim at fostering an understanding of statistical concepts through discovery learning. One can also learn individually with LearnSTATS, although the program was originally designed to be used in a setting of cooperative learning with feedback phases.

FIG. 68
The Structure of LearnSTATS



With the help of the computer, the exercises can be repeated as often as the students think necessary. In most cases, the computer calculates the formulae, so that the students save time and do not have to repeat the calculation if they want to vary the data. LearnSTATS can be employed in a seminar, in group work in the computer pool, and for individual learning at home. Students can also use LearnSTATS as an electronic book with interactive exercises, in addition to a seminar. In the psychological faculty of Hamburg University, students are left to decide for themselves in what way they want to use LearnSTATS.

The System Components of LearnSTATS

The Navigator Palette

The navigator palette (to the left of the screen shot) is always present. It can be positioned either to the left of the exercise window or below the exercise window. The icon buttons in the palette allow the user to skip back and forth between exercises, to open the statistics textbook with explanations and definitions of the statistical concepts, to open a glossary, to open the log book, return to the table of contents, or quit the program.

Glossary

In the illustration, one can see the exercise window with an interactive exercise on the arithmetic mean to the right of the navigator palette, the glossary index on the topic of median values to the left of the exercise window, with the glossary window with explanations on the arithmetic mean on the right. The glossary offers access to explanations of all statistical terms in alphabetically structured form by way of an index browser. The texts in the glossary are kept

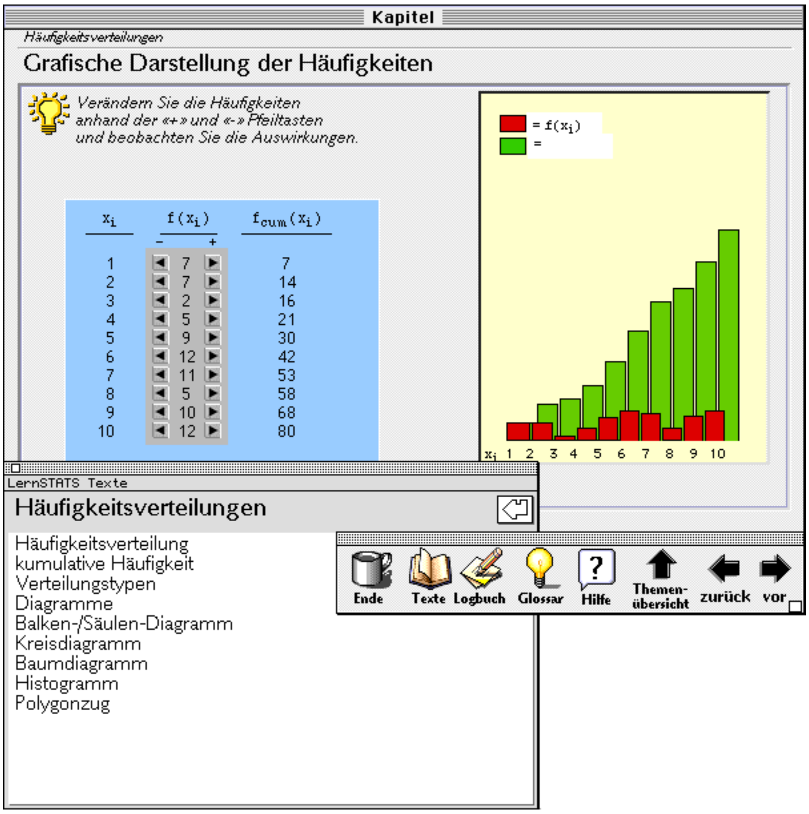
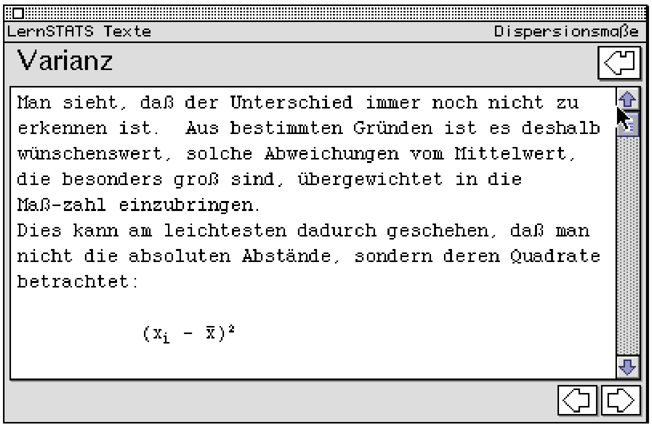


FIG. 69 System Components of LearnSTATS

shorter than those in the statistics textbook, and are thus suitable for quick reference. The glossary is intended for a systematic approach to the theory of statistics, while the statistics textbook is rather a tutorial, which does not merely explain the statistical concepts in its texts, but also treats the students' learning problems, motivates and justifies.

FIG. 70
The Statistics Textbook in LearnSTATS



The Statistics Textbook

The statistics textbook in LearnSTATS is always accessible to the student. It consists of a hypertext browser with a hierarchically structured index. It contains especially simple and easily comprehensible texts on all statistical topics and concepts treated in the exercises [improved text by Bogun/Erben/Schulmeister (1983)]. The textbook window can be kept open all the time. When the students click the textbook button in the navigator palette, the textbook opens on explanations for the current exercise in the exercise window. The texts in the statistics textbook are kept quite simple on purpose, and are very detailed. They were initially edited by the students themselves in the E.L.M.A. project. In comparison to the glossary, the textbook's diction is more tutorial in style and intentionally redundant.

FIG. 71
The Log Book in LearnSTATS

The Log Book

LearnSTATS registers the user when s/he starts the program, and creates a log book for that user, or continues an already existing log. The students' actions are recorded in a kind of protocol (audit trail). The log book records information on the exercise topic, the number of repetitions, the students' input, and the results of the exercise. The students may view the log book at any time, they can give a copy for evaluation to the tutor or teacher, or decide to delete the log information. The log book's purpose is not to control the students' learning processes, but in sensible advice for the students on the basis of their own data.

The exercises in LearnSTATS centre on students' cognitive problems in understanding the statistical concepts , and try to realize certain didactic principles which are important for motivation and cognitive learning: discovery learning, interactive visualization, animation, and learning by doing. All of these build on the students' previous knowledge.

Discovery Learning

Some exercises in LearnSTATS present puzzle and riddles, and give the learner a chance of finding the solution for himself. No precise solution is required, the important thing is rather describing and explaining the cognitive concept.

Interactive Visualization

Two-dimensional methods of visualization illustrate the concepts and relations that have been explained. As a rule, graphs and tables of values are linked in such a way that interactions in the table are immediately mirrored in the graph and vice versa. Diagrams can be accessed by the students through direct manipulation.

Animations

Animations illustrate functional mechanisms of formulae by successive highlighting of the data to be calculated, or by a visual »drifting« of the data into the diagram.

Learning by Doing

All exercises in LearnSTATS can be repeated. As a rule, the student may vary the data sequence that forms the basis of the exercise. Formulae are broken down into parts and can be put together again through direct manipulation.

Concepts and Subconcepts

Complex concepts are broken down into a series of subconcepts. Thus there are several exercises on the arithmetic mean, on variance, and on correlation. The calculation of factor analysis for example contains exercises on matrix algebra, on the calculation of loads, on factor extraction, and on the rotation of factors.

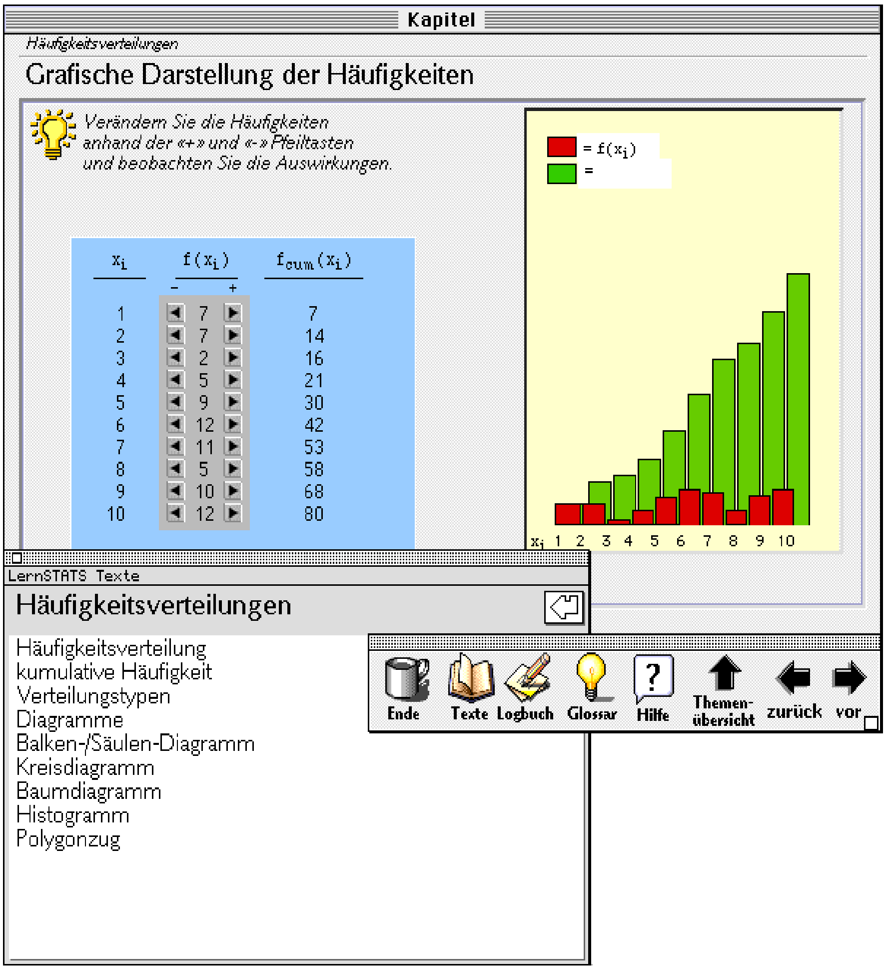
LearnSTATS is currently being tested by roughly 50 university teachers of statistics in several European countries, among them the Fernuniversität Hagen. I have received detailed feedback from some colleagues which is currently being worked into the program.

Some Sample Exercises from LearnSTATS

In the following, I am going to describe some exercises from LearnSTATS, although this can only be partly successful, because the illustrations cannot show the animations and interactive processes that happen in the build-up and execution of the exercises.

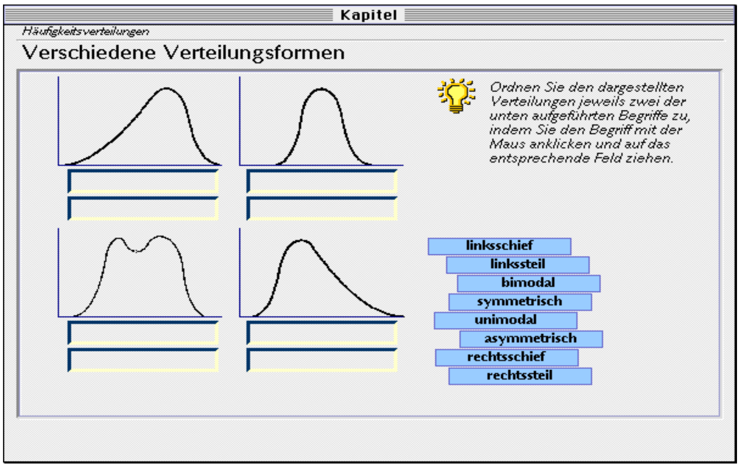
Interactive Graphics

FIG. 72
Exercise on Frequency Distribution with Textbook



The exercise calculates frequencies and displays them in the form of a bar chart. Behind the bar chart, a diagram of cumulated frequencies appears. Students can change the values in the frequency table with the help of the arrow buttons, whereupon the two diagrams are drawn afresh. But the students can also manually enlarge the bars in the bar chart, or make them smaller, which is mirrored immediately in the values in the frequency table. Most exercises on diagrams in LearnSTATS are bidirectionally interactive, i.e. either the values or the diagram may be manipulated.

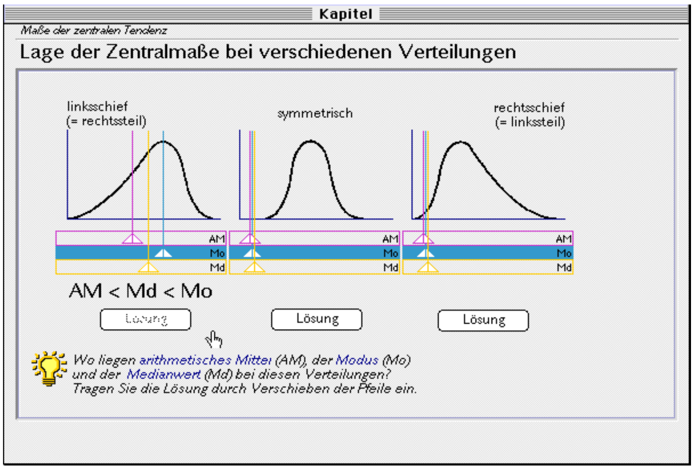
FIG. 73
Exercise on Distribution: Classification



The illustration shows an exercise on distribution shapes. In this case, the students are asked to classify the illustrated distributions by way of attributes. The features can be »pasted« into the fields beneath the distribution shapes with the mouse per Drag & Drop. If a classification is incorrect, the label with the attribute »flies« back to its position.

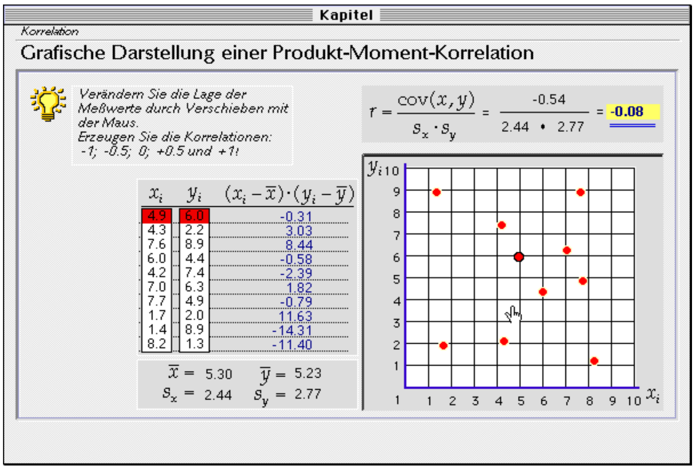
The next illustration shows an interactive diagram whose aim is not the assigning of attributes, but concept relationing: mode, median, and arithmetic mean are to be positioned correctly for the distribution shapes positively skewed, negatively skewed, and symmetrical:

FIG. 74
Interactive Graphics: Position of Median Values



The students can move the median values of arithmetic mean, mode, and median, which are represented by vertical lines, to their correct position by dragging the lines with the mouse.

FIG. 75
Correlation: Interaction of Values and Graph



One of several exercises on the product-moment-correlation is depicted in the above illustration. The correlation exercises emphasize the concept of covariating pairs of variables. In the exercise above, the variable pairs are transferred into the scatter diagram by way of animation. The students can move the points around in the diagram. The corresponding pairs of values will be calculated afresh accordingly, as will the correlation. Students are given the task of finding constellations of points that result in correlations of +1.0, -1.0, +0.5, -0.5, 0.0 etc. The enactive form of dealing with this topic helps the students to develop a cognitive understanding for the concept of covariance and correlation, a prerequisite for developing a more formal version of this concept.

Manipulation of Formulae

Special interactive exercises were developed for learning formulae. We wanted to avoid the students having to do the partly very difficult calculations themselves. Nevertheless, they were to reach an understanding of the calculation algorithm. This objective was achieved by breaking the task down into partial tasks. In the exercise on variance, the students were supposed to calculate the variance value by letting parts of the formula be calculated and inserting the result by Drag & Drop into other formulae. The first illustration shows the start of the exercise:

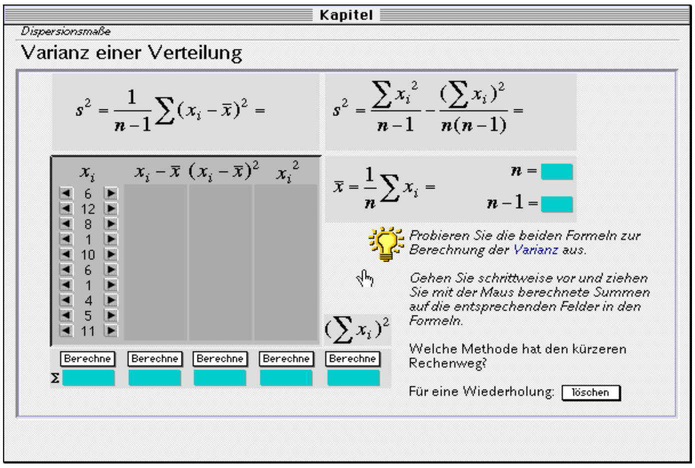


FIG. 76
Exercise on Variance: Calculation of Parts of a Formula

The next illustration shows the exercise after all steps have been calculated. The places in the formula that are possible insertion places for the results are highlighted in blocks (the numbers have already been entered):

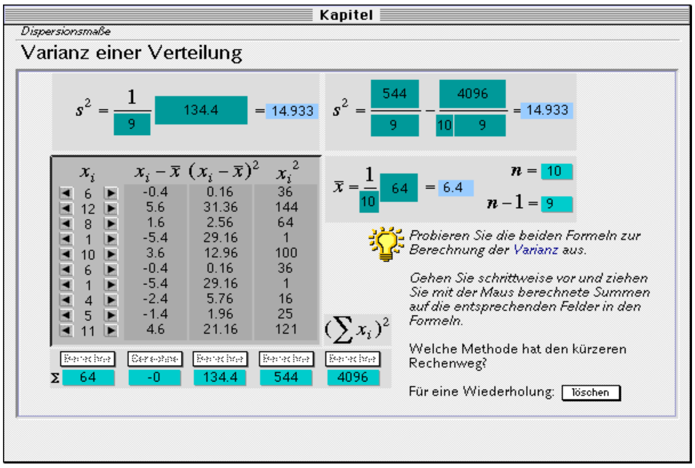


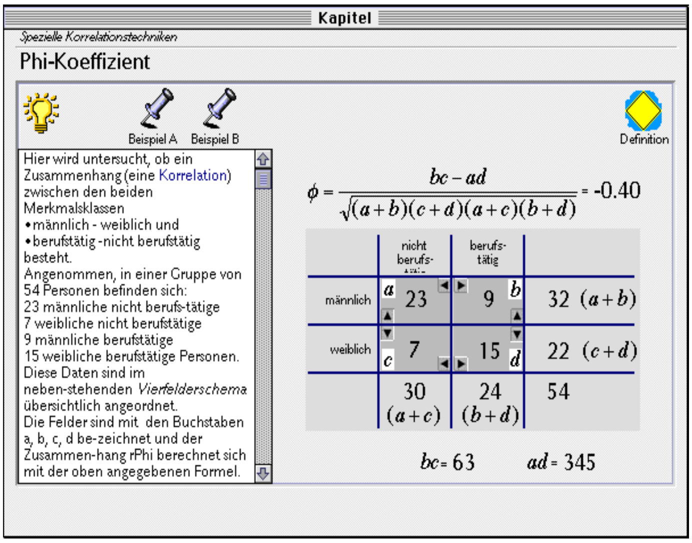
FIG. 77
Exercise on Variance: Inserting the Partial Calculation Results

This exercise again works with the method of direct manipulation, i.e. the calculated partial results are »picked up« from their respective fields with the mouse, moved over the areas of the other parts of the formula into which these values might be inserted, and are finally »dropped«. If the position is correct, the values are placed in the respective parts of the formulae and can be used for the calculation of these formulae in turn.

Relations as Tables

A table is a relational concept on a higher level. The concept of quantity becomes the concept of frequency, the concept of the list becomes the concept of cells, columns, and rows. Tables are important for non-parametric correlations in particular. The students can raise or lower the values in the cells with the help of the arrow buttons, and observe the effect on the calculation. In the following illustration, I depict the exercise on Phi correlation:

FIG. 78
Exercise on Phi Correlation



Learning by Repetition and Exercise

Many exercises obtain a special learning effect because the students may repeat them as often as possible. Converting the presentation of a textbook into exercises would be much more difficult, because the students would then have to do all the calculation on their own, which mostly does not offer any learning benefit. The learning benefit of such exercises lies mostly in the comparison of results. It is only by raising or lowering values that one can discover causal links. In computer-supported exercises, the program relieves the students of repetitive tasks and allows them to concentrate on the concepts behind them.

Concepts of Logical Relations

The logical problem of selecting the correct type of correlation is conceptualized as a decision matrix in LearnSTATS. The two dimensions of the matrix are formed through the scale quality of the two variables. The students are asked to select a certain type of correlation for the solution of the problem, and must afterwards find out through questioning, like in a miniature expert system, whether their choice was correct.

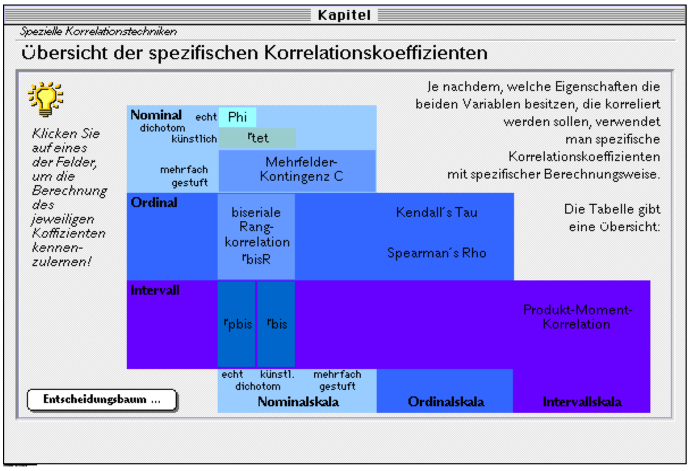


FIG. 79
Decision Matrix for Correlations

Motivation and Understanding

LearnSTATS contains a number of exercises on factor analysis, among them a factor rotation in a three-dimensional scatter plot, as well as an example for the rotation of data in three-dimensional space. The three-dimensional case especially supports motivation, the basis for a three-dimensional understanding of factor analysis. Only when factor analysis has been motivated thoroughly enough does it make sense to go on to the technical aspects of factor analysis. The technical aspects treat a complete factor analysis, subdivided into several partial steps, into matrix algebra, data rotation, factor extraction, factor rotation, and factor interpretation.

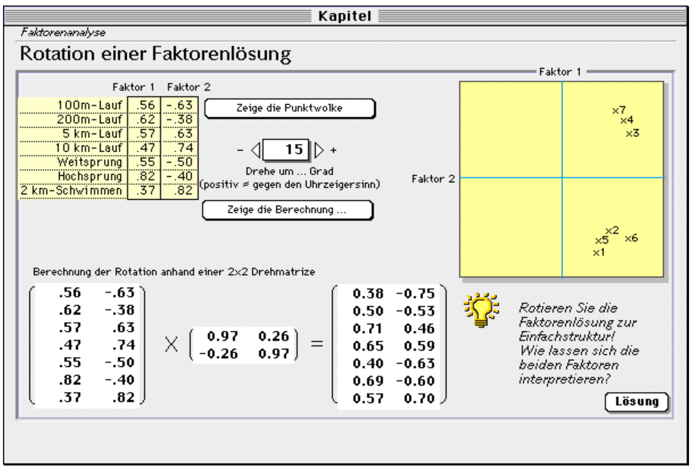


FIG. 80
Rotation of a Factor Solution

Learning Geometry with Geometer's Sketchpad

It is only seldom now that a program fills me with such unmitigated enthusiasm as is the case with *Geometer's Sketchpad*. *Geometer's Sketchpad* calls itself »the first dynamic geometry software« – which is quite true. The smart little thing is based on a book by Michael Serra, »Discovering Geometry: An Inductive Approach«. Nick Jackiw developed the program in a project supported by the National Science Foundation under the direction of F. Klotz (Swarthmore College) and D. Schattschneider (Moravian College).

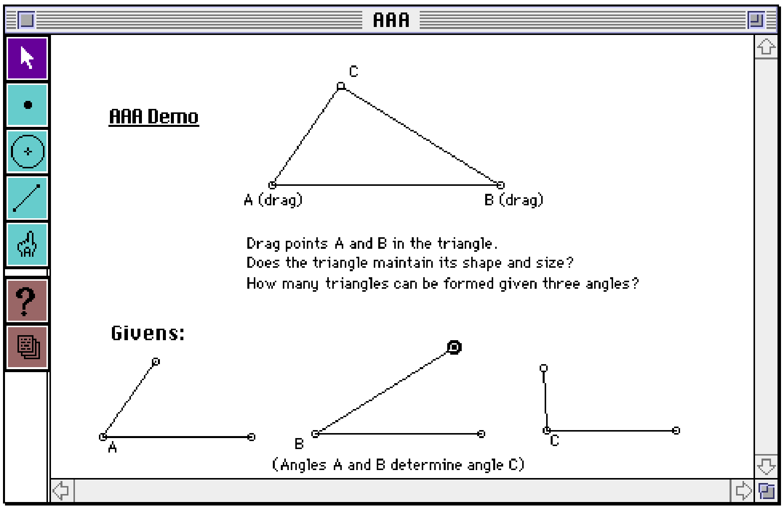
Geometer's Sketchpad facilitates an explorative, discovery-oriented approach of the student to geometry, because the individual graphic elements or objects can be connected to each other and moved and calculated as geometric (and not just graphic!) objects. The program's abilities comprise the following (and more):

- drawing of geometric objects
- manipulation of geometric objects (length, angles etc.)
- calculation of lengths, spaces, angles etc.
- automatic labelling of the objects
- manual animation with and without tracing
- recording of scripts
- playback of scripts (animation with and without tracing).

Apart from the basic functions of drawing with graphic objects, the program also has geometric knowledge: Thus *Geometer's Sketchpad* does not understand two lines that touch each other at a point of intersection as static objects. The intersection acts as a pivot. If the user moves one side of a triangle, the opposite corner point remains fixed and all angles adapt to the new constellation. The program always knows what a side and what an angle is, can calculate lengths of sides and angles, and treat a line within a circle as a radius. The drawing possibilities extend to mirror-symmetrical images, inversions, tangents, and many other features. All forms are of a sophisticated simplicity that allows the student to play around with them long before s/he knows their geometric names. In a second step, the program automatically labels objects after the traditional manner (points: A, B, C; sides: j, k, m etc.). The labels can be turned on or off. There is a text editor for entering longer texts. In this way, the teacher can construct exercises with teaching instructions or comments, which can be calculated automatically, and whose objects can be manipulated interactively.

Sketchpad also calculates the lengths, areas or angles, the sum of angles in a triangle, the length of a side, the inclination of a line, area, circumference and radius of a circle, and any sensible combination of these parameters. The calculated values are superimposed on the object.

FIG. 81
Automatically Labelled Triangles and Angles



Above all, Sketchpad allows the direct manipulation of geometric concepts: For this, several objects must be selected and connected in such a way that when one object is moved, the other will be moved, too. Thus e.g. a movable point on a line can serve as a slide control with which to change the radius of two overlapping circles. Movements can be automatically traced and recorded. Thus moving the intersection of two circles may result in an ellipse, or rotating a point around the circumference of a circle may set off a moving sine curve.

The animation options in Geometer's Sketchpad might be called a follow-up to tracing technique with other means. Two or more objects can be selected, which the program will then put into motion automatically.

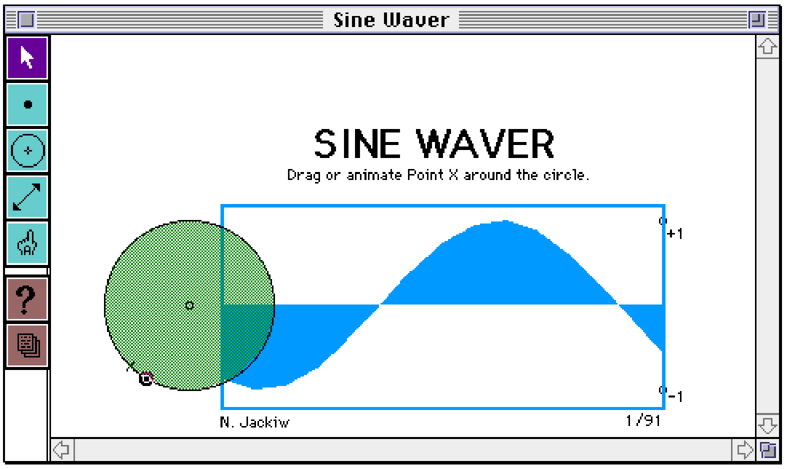


FIG. 82
The Point on the Circle's Circumference Drives a Sine Wave

The individual steps in the construction process can be written into a script, and the script can be played back at any time. Scripts can be nested recursively. The recorder protocols the given conditions and all further operations executed on this basis, e.g. »points A, B, C; segment from A to C«. The script may be used again on the given objects under the same conditions. If a script is executed repeatedly, the impression of an animation is created.

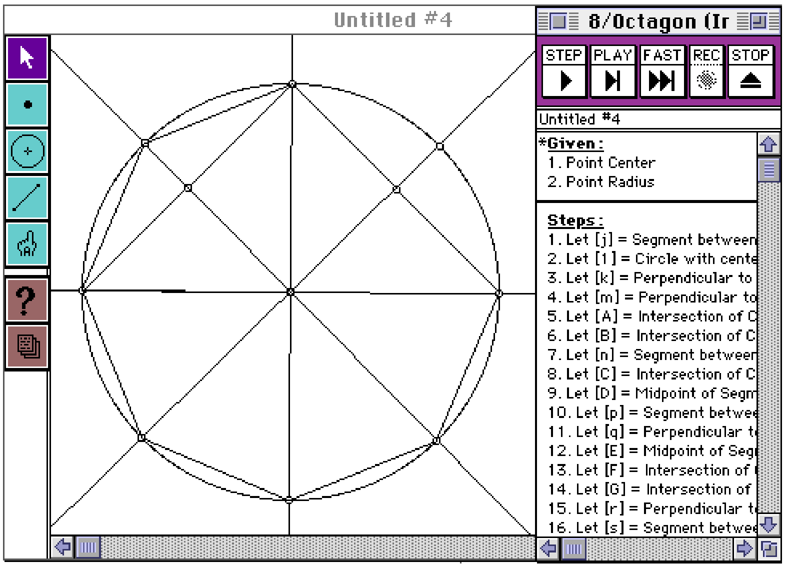
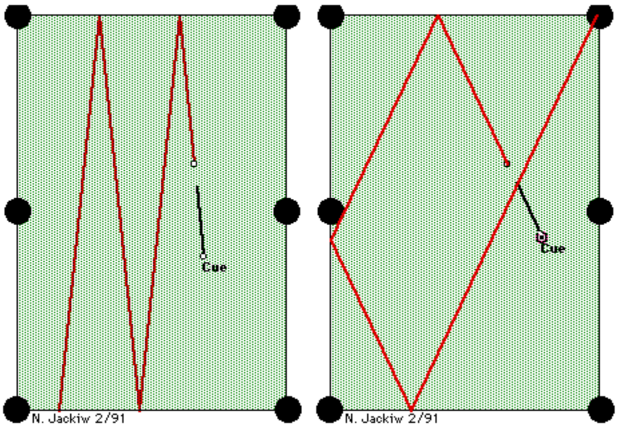


FIG. 83
Automatic Generation of an Octogon through a Script

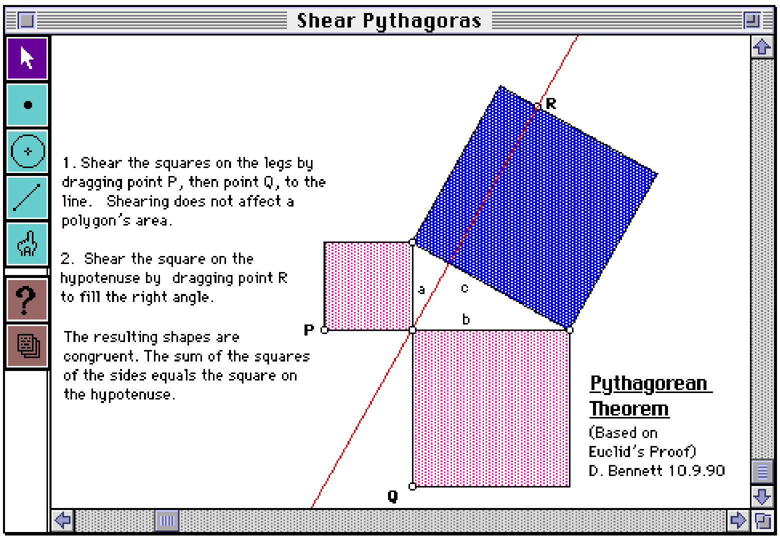
The result is not simply geometry, but a kind of »dynamic« geometry, geometry as a moving, living process.

FIG. 84
Billiards: The Ball's Course May Be Altered



There is no question in my opinion that this dynamic treatment can assume a particular cognitive relevance for constructive and graphic learning processes in students. The developer has achieved a completely new concept of a cognition-psychology-oriented approach to the problem of teaching geometry. Before geometry comes the cognitive concept. The spatial-visual manipulation of geometric objects follows, and the inference conclusions ensue almost automatically. Even mathematical proofs can be executed in the program by way of pure geometric manipulation and visual comparison. Let me give an example here, which probably everybody remembers from school: prove the Pythagorean theorem $a^2+b^2=c^2$ without calculating the areas, purely graphically!

FIG. 85
Pythagoras in the Original State



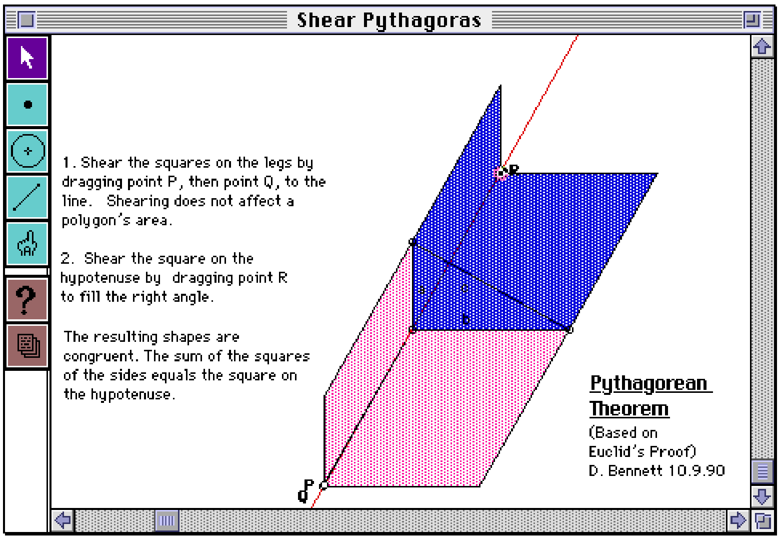


FIG. 86 Pythagoras after Transformation of the Squares into Polygons

The authors of the program also propose certain learning situations, and for this purpose provide electronic sample exercise sheets for the teacher:

- Demonstration by the teacher (expository learning)
- Exploration of given exercise sheets by the students (guided discovery learning)
- Studying problems and geometric projects (discovery learning)

Similar functions as in *Geometer's Sketchpad* are offered by the programs *Interactive Physics* [Gentner 1992] und NEWTON [Teodoro (1992)] für die Physik.

Mathematical MacTutor

The *Mathematical MacTutor* (St. Andrews, Scotland) allows the direct manipulation of mathematical objects. The environment can be considered exemplary for the transformation of mathematical problems into discovery learning situations. Sometimes, the mathematical problem is not easily recognized beneath its trappings (e.g. Escher graphics, tangram figures). What the students manipulate with this instrument is conducive to fostering the individual construction of cognitive concepts. An important element of *Mathematical MacTutor* are hypertexts on the history of mathematics, which can be called up in the individual exercises and extend the students' understanding by a historical dimension, a dimension not yet addressed in this book, because none of the programs presented up to now, least of all the natural science programs, had included the historical dimension.

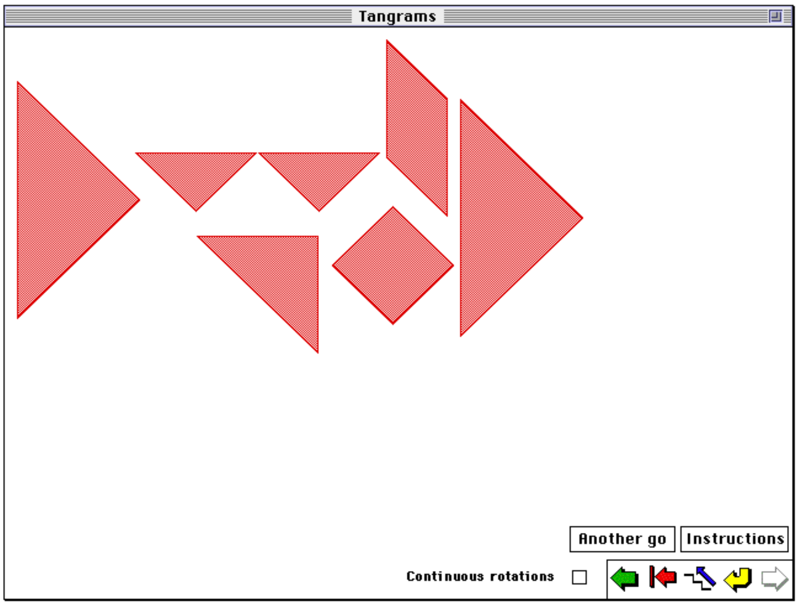


FIG. 87
Tangram Exercise from *Mathematical MacTutor*

Tarski's World

Even in philosophical logic there may be meaningful opportunities of employing creative learning and exercising programs of the direct manipulation type, which allow active construction, e.g. the original program *Tarski's World* by Jon Barwise and John Etchemendy (Stanford University; distribution: University of Chicago Press), in which logical sentences can be tested on 700 variously complex problems in more than 100 exercises [Greeno (1991), 7ff]. The system consists of an editor for logical-semantic expression, and a pictorial representation of a domain world that consists exclusively of three-dimensional blocks in various shapes in a quasi-three-dimensional pattern. The locations in the pattern represent relations like to the left of, to the right of, in front of, behind, and between. The students' task is to generate logical expressions and find solutions with the help of the analogies between expression and pictorial representation in which all logical expressions are true. *Tarski's World* comes with a number of models and theorem files which the student can use for practise, e.g. Wittgenstein's World, Leibniz' World, Boole's World. The program also offers a »play mode«, in which student and computer change sides.

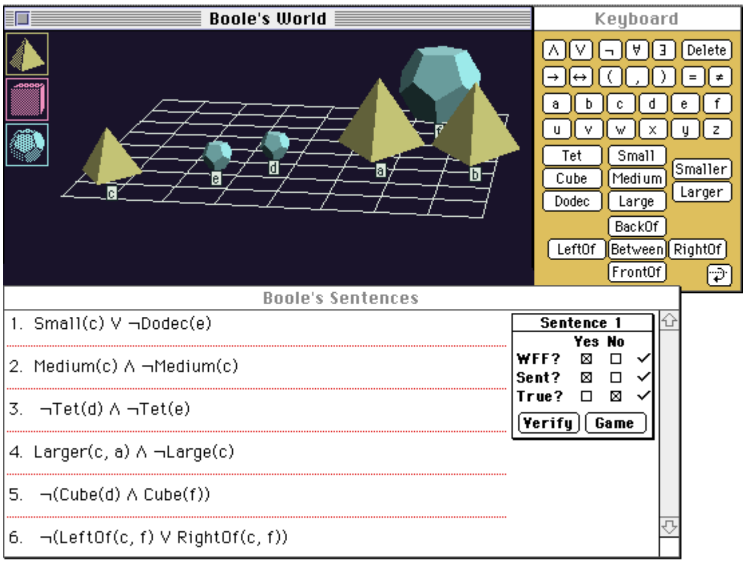


FIG. 88
Tarski's World: Testing the Logic of Models

Learning Tool

Learning Tool, a variation of MORE or *Acta* [Kozma (1987)] turns a hypertext principle (outline with nodes and graphical maps) into a learning tool. *Learning Tool*, which Kozma (1992) also sees as a cognitive tool, consists of a shell with three different levels: a master list, borrowed from the outliner principle, a concept map, in which each new line creates an icon, which in turn refers to the third level of note cards, into which the learner can enter his texts and pictures. The tool thus allows the user to create texts that are connected to each other by relations in the manner of an ideas generator, and thus symbolize the semantic web of relations in the texts. Kozma (1991) reports a study in which *Learning Tool* and the outliner *Acta* were used to support learning in English composition.

TextVision

A relatively similar system is *TextVision* for the Macintosh [Kommers/de Vries (1992)], with the difference that TextVision is based on a kind of graphics editor, in which nodes and links are positioned graphically, and texts can then be attached to the nodes.

SemNet

In a similar way *SemNet*, a kind of three-dimensional colour web editor for large knowledge bases, offers the user the opportunity to represent elements of knowledge, cognitive or semantic relations as fisheye views and clusters. The spatial-metaphorical interface transfers measures like distance and thickness into weight, and lets the user navigate in three-dimensional space with the help of relative and absolute movements [Fairchild/Poltrock et al (1988)]. The links in *SemNet* are bidirectional and can be typed. The representation with regard to neighbours, direction, and type of link depends on which node the user selects.

The selected node is moved to the centre, the neighbours become satellites [Allen/Hoffman (1993), 263].

IQON

IQON (Interacting Quantities Omitting Numbers) is a tool for modelling qualitative or semi-quantitative arguments that works with icons, following the working method of STELLA [Miller/Ogborn et al (1991)].

DISCUSS

With DISCUSS, Decker, Hirshfield et al (1989) introduce a tool for creating arguments that is subdivided into an authoring and a student part. The authoring part works with diagrams for arguments, and different icons can be added to the arguments. The student part presents questions to the students, which they can then answer. The instrument was used in courses on political science and literature. The teachers noted a marked improvement of seminar discussion and a higher quantity of texts. Their expectations regarding the fostering of higher cognitive abilities or critical reasoning were not fulfilled, however.

Writer's Assistant

Writer's Assistant is a tool meant to support the writer in his work [Sharples/O'Malley (1988)]. Argument is constructed as a network in this instrument as well, a web whose nodes open writing pads. In a fisheye view, an excerpt can be viewed as continuous text.

Designers' Notepad

Twidale, Rodden et al (1994) describe informal observations from the employment of *Designers' Notepad* (DNP) in four student workgroups. DNP was initially intended as a tool for the early phases of software design, »but whose features are equally applicable as a learning environment for students of any domain« (107). The tool is a kind of flow chart editor with additional windows for notes, and the possibility of typing the links. Twidale, Rodden et al go into the differences to *LearningTool* and *SemNet*, and emphasize the great variability and flexibility in using their tool. The observations with regard to possible functionality are interesting: one might work out the concept in one's head and only use DNP afterwards as a graphics editor, or be seduced by the graphic quality of the tool into only worrying about making the diagram more precise and forgetting all about the contents.

Larkin and Chabay (1989) present four programs which have received the EDUCOM/NCRIPTAL Software Award. All programs have different aims, but they all have the interactive approach in common:

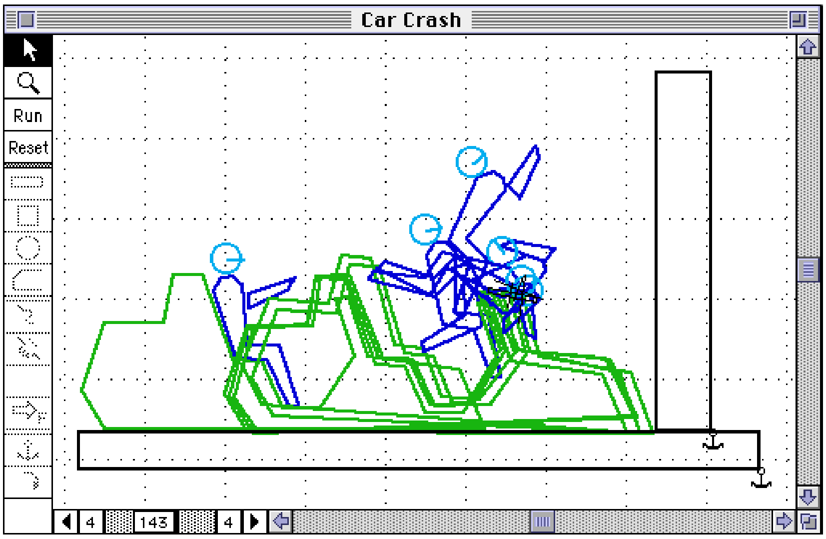
CHEMAZE is a PacMan-like game with chemical substances in a labyrinth, which must be removed from the path through chemical reactions. The player can only achieve success if he knows the substances, i.e. their classification according to their chemical characteristics, and knows the products created in the reactions.

The program *Graph and Tracks* allows the interactive manipulation of an inclined plane and displays the movement of a ball on the inclined plane in the form of a curve. The learner's task is to generate a movement corresponding to the instructions by arranging the inclined plane.

Physics

In physics, it is especially interactive simulations that are important in teaching. The program *HyperPhysics* received the German-Austrian Higher Education Software Award for physics in 1993, for the generation of physics simulations characterized by a consistent and attractive graphical user interface. Singer (1993) describes *Circuit II*, an interactive program on electronic circuits that can be manipulated graphically, and to which questions my be put. The following illustration shows the animated simulation of a car crashing into a wall from the program *Interactive Physics* by Knowledge Revolution, with the help of which simulations of graphical objects can be constructed according to the laws of physics.

FIG. 89 Crash Simulation with *Interactive Physics*



Optics Dynagrams Project

With the *Optics Dynagrams Project*, Pea (1992) describes a program allowing interactive construction in the field of optics. The program is on the borderline between an interactive construction program and a simulation program, because it knows the rules of reflection and refraction, and can simulate these processes. The diagrams are suited as a stimulation to training in qualitative scientific argumentation. The simulation model facilitates actions like explaining, predicting, modelling, designing and finding mistakes. One can imagine that such an instrument can no longer offer a complete, totally administrated learning process. That is why Pea puts strong emphasis on embedding the instrument into the social learning process through conversations between teacher and student according to constructivist ideas. The small group dialogues reported by him mirror a quality of linguistic argumentation that will probably never be matched by IT systems. At the same time, the experiment made clear the function and role of the teacher: the teacher is »critical in serving as a guide to establishing productive inquiry situations, and in providing the kinds of integrative questions that will lead students toward scientific norms and practice« (338).

CUPLE

The CUPLE project (The Comprehensive Unified Physics Learning Environment) is an attempt by several American universities to combine a multitude of multimedia physics programs within the uniform interface of *ToolBook*: text, laser discs, virtual laboratories, and simulation programs [Redish/Wilson et al (1992)]. The programs from the earlier M.U.P.P.E.T. project of Maryland University are also integrated in CUPLE. The authors see CUPLE's main function in fostering the students' physical reasoning.

Further examples for mathematics and natural sciences can be found in Schaufelberger (1989) of the ETH Zurich. These are *HyperCard* programs which can be used in connection with *Model Works*, *Matlab*, and *Mathematica*. The presentation level makes use of typical models: laboratory, textbook, calculator.

Learning Constellation

With her program *Learning Constellation*, which is based on *HyperCard*, Goldman-Segall (1992) wants to foster multiple reading of texts, the genesis of meanings, perspective viewing of videos, as well as taking up multiple perspective in ethnology. The program allows giving a commentary on video scenes taped at the Hennigan School in New York, at which Seymour Papert also carried out »Project Headlight«. Video ethnology mostly demands hermeneutic interpretation, which is supposed to be fostered through the various tools for working flexibly with video.

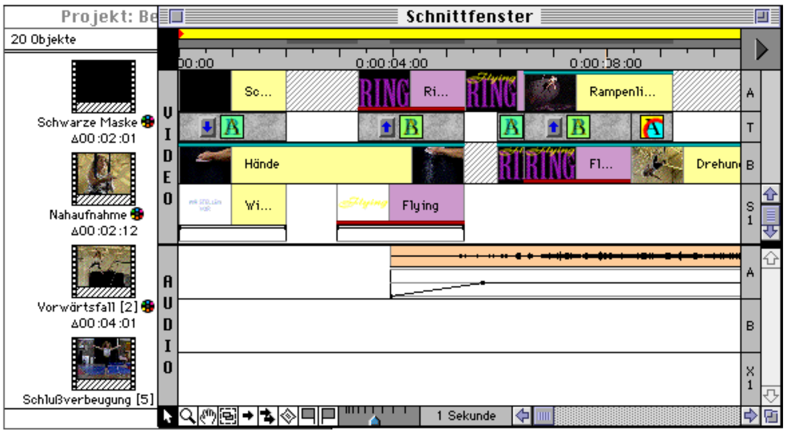
Voxel-Man/atlas

In medicine, VOXEL-MAN/atlas by Pommert, Riemer et al (1994) is a 3D visualization of the human brain in the form of an atlas. Students find a highly interactive three-dimensional environment in the atlas, which makes the human brain accessible in partial segments as 3D objects or in layers at any time. The authors point out that hypermedia components and tutorial components can be combined with the 3D atlas in such a way that intelligent search options result for the learner. An interactive 3D atlas for anatomy is also described in McCracken and Spurgeon (1991), and Höhne, Bomans et al (1992).

Interactive Tools for Multimedia Production

Concluding this section I would like to point to programs that also belong to the field of interactive tools, but whose main purpose is multimedia production. These tools are well known, because they are distributed commercially and are used by almost everybody who is practically involved with multimedia, so that I do not have to introduce them here at length. I only want to mention them for completeness' sake, because they are interactively constructive programs themselves that use multimedia for producing multimedia. The following illustration shows the program *Adobe Premiere*, in which digital films can be assembled, provided with a sound track, and edited with dissolves:

FIG. 90
Adobe Premiere:
Composition and Editing for Digital Films



These tool programs function in an object-oriented way, everything in them works through direct manipulation, and they use their own metaphorical worlds as interfaces. As one example standing for many, I only want to mention *Macromedia Director* for the development of animations and Kiosk systems, *Adobe Premiere* for digital video editing, and *Cubase* by Steinberg for musical composition and setting films to music, to name just a small selection. The next illustration shows the program *Cubase Audio* (Steinberg), with which digital music productions can be composed:

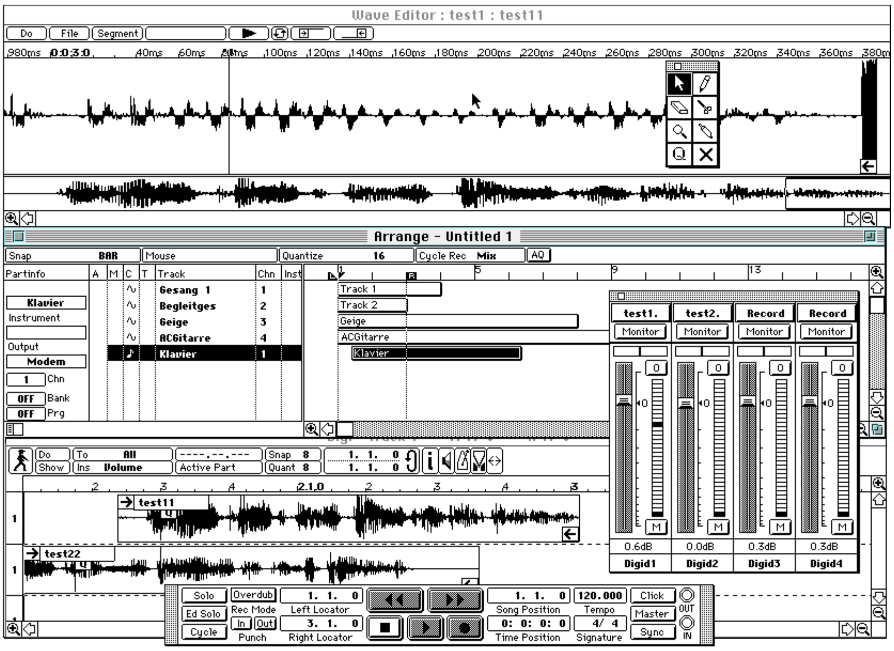


FIG. 91
Cubase Audio: Digital Music Composition

Multimedia Tools for Research

In the last section but one I introduced programs that employ multimedia or hypermedia for learning, in the last section I discussed programs serving as tools for multimedia production. In this section, I would like to introduce a single program that employs multimedia for research instead of the other way round, i.e. which contains multimedia as resource, object, and method, in order to make contributions to research with the help of this means. There are very few programs of this kind up to now that produce research with multiple media. Borderline cases on the way to this aim are molecule editors in chemistry, whose three-dimensional graphics only have an illustrative function as a rule, however, or collaborative tools for group argumentations like SEPIA, whose multimedia components are however only a tool, rather than the research object. The program I would like to introduce is called syncWRITER (med-i-bit, Hamburg). syncWRITER is a multimedia tool for the interlinear transcription of conversations and interactions that have been recorded on audio or video tape.

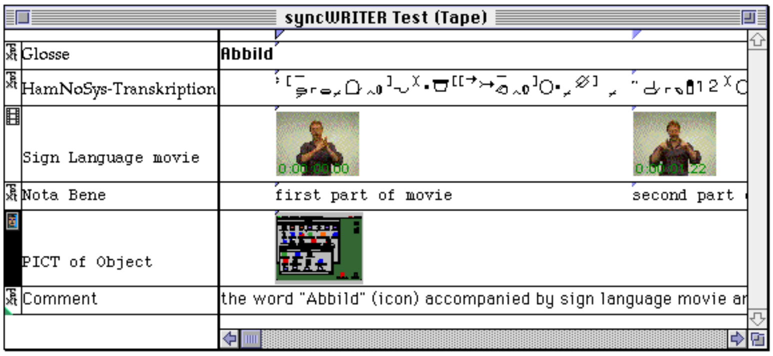


FIG. 92 Multimedia Endless Editor for Transcriptions

The study of oral communication (instruction research, therapy research, social interaction research, conversation analysis, media analysis) is a relatively young and innovative field of research in the arts and social sciences. The common word processing program is not suitable for the transliteration of conversations, because it automatically wraps lines at the right-hand margin. The interlinear transcription of conversations or interactions needs a software that allows the recording of several »voices« or »parts« in endless tracks, and that can synchronize these tracks at any given point in time. It must also be able to generate a synchronous depiction of conversations with several participants out of the principle of score notation. Such a program is also suited for a synopsis of different versions of a text (e.g. poems, translations, law).

The program syncWRITER, which received the German-Austrian Higher Education Software Award in 1990 [Hanke/Prillwitz (1995); a demo version for Apple Macintosh computers can be downloaded at <http://www.sign-lang.uni-hamburg.de/software/software.html>] offers a solution for this task. It records the various parts of the conversation in separate tracks. These tracks may also contain a video or audio recording of the conversation scene, which can be played back (from a digital file, or via access to a VCR). Films are automatically provided with a time code. Movies and sound in tracks can be cut down into smaller segments, which can be attached to the synchronization points (SyncTabs) in the transcription. The video and audio pieces can be played back repeatedly in transcribing at any time. If there is an editing action, all transcription segments attached to a SyncTab move to the left or right automatically. syncWRITER can also generate lists of transcription texts according to utterance boundaries and statistics of the texts. The program represents multimedia at the line where multimedia becomes the norm, a natural everyday tool. The program can be gainfully employed in research, but at the same time, it can also serve as an introduction to the problem of interlinear transcription for students.

CHAPTER 11 Sand-Table Exercises

Learning in Model Worlds with Simulations

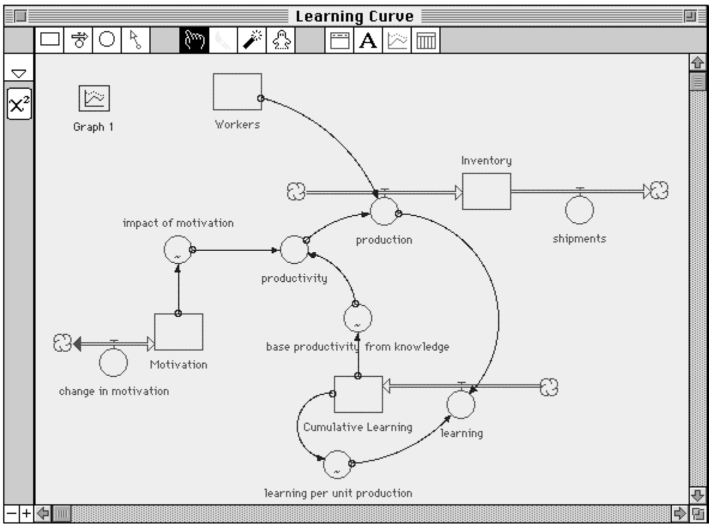
With modelling and simulation, we have reached the borderline of the multimedia area. Many modelling programs use only one medium. But modelling has two points of intersection with the topic: simulations are a particular variant of the type of program I have called »interactive learning programs«, simulations are often integrated into programs following the microworld approach (*Refract*), some make up the core of intelligent tutoring systems (*Voltaville*, *Smithtown*, STEAMER), or interactive construction programs (*Interactive Physics*), and they are also integrated into other multimedia programs (*SimNerv*). Finally, they are one of the supporting pillars of constructivism (Alan Kay's *Live Labs*). Simulations are a special form of interactive programs. They can be used as tools, but also as learning programs. They are ideally suited to the analysis of discovery processes [Langley/Simon et al (1987)].

More often than not, simulations were initially created as research instruments. Even when they were expressly developed for the sake of learning, like the many smaller simulations in physics and mathematics, they do not possess or proclaim learning objectives as a rule [Hartog (1989)], and do not provide any didactic methods. What they usually lack is an environment in which the simulations could be integrated into exercises and which offers access to explanatory texts. If provided with a sensible user interface, simulations are an ideal medium for teaching dynamically changing subjects [Reigeluth/Schwartz (1989)].

Simulations are dynamic models of machines, processes, and systems. Many simulations consist of large mathematical models with 20 to 200 differential equations [Hartog (1989)]. Especially well known are simulators, models that simulate other machines, like e.g. computer systems, aeroplanes, space probes, ships, submarines, cars, control systems for power stations etc. Many of these systems are employed especially in the military sector and the industry, for training flight personnel, maintenance personnel, and similar professional groups. What has made them popular is the flight simulator for the PC. Less well known are models of biological, economical, ecological, and political-social systems. The computer games *SimCity*, *SimAnt* and *SimLife* have brought some popularity to this area recently.[28]

Simulation programs usually consist of two parts: the model of a system, and the dynamic calculation of the modelled system, with the model part consisting either of a programming language as interface, or of an editor for graphical objects, as in the following illustration, which represents a model for the cycle of learning in *ithink*.

FIG. 93
Modelling a Simulation in *ithink*



The simulation part of a program may also consist of either diagrams and animations, or statistics and tables. Reigeluth and Schwartz (1989) classify the representational form of simulations with Bruner's terms as enactive, iconic, visually symbolical, and verbally symbolical (3). A central characteristic of simulations is that the current state of the model is constantly calculated, and that this calculation can be influenced through parameter variation. In this sense, simulations are highly interactive programs, with the kind of interactivity varying from mere parameter modification to the direct manipulation of graphic objects.

28.A comprehensive list of simulations and modelling programs with suppliers will be found in Garson (1994), who mostly deals with business sciences, social sciences, and history.

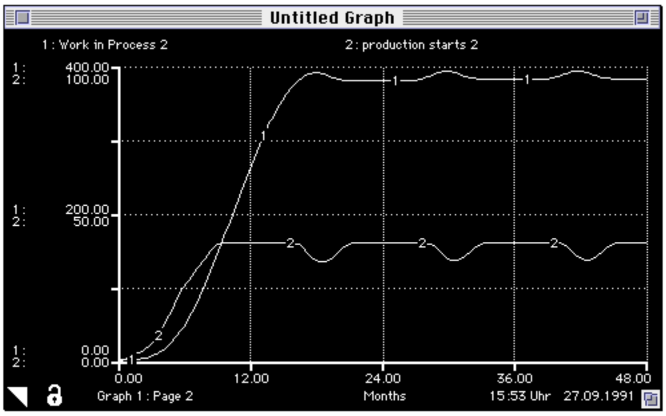


FIG. 94 Diagram of a Simulation Progress from *ithink*

A simulation, according to Borsook and Higgenbotham-Wheat (1991), is the most highly interactive type of program: »It allows a level of interactivity not rivaled by many other types of computer software« (16). But what type of interaction is this? There are very high-level cognitive aims involved, such as creating images, modelling systems, forming hypotheses, testing hypotheses. More recent simulations offer object-oriented interfaces for this purpose that allow modelling by way of direct manipulation. As soon as the model is established, many interactions consist of actions like calculating, animating the model and reporting back the results, choosing between graph and table. Even more complicated processes, like e.g. hypothesis generation, can be facilitated by a »didacticizing« of the interfaces: thus Shute and Glaser (1990) integrate a menu into the simulation that serves to generate hypotheses. Simulations seem to be a very similar form of interaction as that offered by the graphics, geometry, and physics programs discussed in the previous chapter, or the cognitive tools for constructing chains of arguments.

The difference to interactive learning programs lies in a special limitation of interactivity: simulations are bound to the instrumentalized logic of scientific modelling: »The design of the simulation is based on Popperian scientific method, but Popper described the logic of scientific discovery, not the history of it« [Laurillard (1987)]. Simulations model themselves on scientific research and experiments, rather than a heuristics of discovery. But they can be didactically employed in explorative situations. Laurillard sees simulations as an educational innovation with regard to the difference of didactic and communicative learning methods, and the three dimensions of control: »There are three ways in which the simulation is a pedagogical advance on the conventional tutorial form: (a) it gives the student direct access to the domain model, rather than mediating this through dialogue; (b) because of this, the explanations are implicit in the behaviour of the model, giving the student experience of its behaviour, rather than being articulated through a verbal description, which only tells about the behaviour; and (c) the student has complete control over the solution path«.

According to Laurillard, a simulation is a compromise between a traditional learning program and an intelligent tutoring system. But what about the educational, didactic use of such systems? Can one expect from learners that they will learn independently with environments as complex as this? It is often difficult for beginners to achieve working models. As an intermediary concept that might show learners the way to an appropriate planning of models, Hartog discusses a qualitative, causal model that plays a part in human everyday reasoning. Even if certain forms of causal reasoning are non-scientific, says Hartog, one must not overlook the fact that they play an important role for learners. A simulation follows such specialized rules that beginners cannot learn the method of modelling intuitively: »If we allow the student to be the author, there is little hope that they will learn Newtonian physics«. Laurillard concludes from this that a kind of »didactic sequence« from simple to more complex simulations must be constructed in order to gradually introduce the learners to the use of a modelling system. But if one adds such a »didactically« motivated strategy of introduction to a simulation, one does not get a simulation in its pure form any longer, but rather a tutorial environment with superimposed simulation. It is this combination that Laurillard aims at with her conclusion from observations that students do not find out the important experiments their teacher had envisioned if given free choice: »they are never likely to hit on the crucial experiments […] These have to be provided, and the students have to work through them in order to experience the necessity of changing their original conception«. The distinction between the methodological classification and the educational classification of simulations that Laurillard makes receives a nasty consequence here. The observation that beginners understandably have not yet mastered the method of modelling leads to an instruction which forces the students to re-enact prefabricated examples. This conclusion is not compelling. An educationalist would have seen more possibilities here, and would probably have access to a more varied repertoire of methods, so that one would not in the end have to cancel the methodological characterization of the simulation as an interactive program for discovery learning.

Many approaches to and explanations of learning with modelling programs and simulations develop out of problem-solving or discovery learning. Others develop out of the learning environments, situated cognition and constructivist approach. What these approaches have in common lies in the following characteristics of modelling and simulations: simulations require the generation and testing of hypotheses; the latter must be done in a deliberate way, because it is impossible otherwise to draw meaningful conclusions from the processes and results of the simulation. Klahr and Dunbar (1988) have developed a general model for this purpose, which they call SDDS (Scientific Discovery as Dual Search). Classifications of the learning processes in learning with simulations often show a mixture of criteria taken from problem-solving or discovery learning [Goodyear/Njoo et al (1991), 272]. Some researchers apparently view the problem-solving processes occurring in programming, often called meta-cognition, as a pre-schooling for logic and reasoning. Clark (1992) has strongly opposed this idea (282).

Phases of Learning in Simulations

One can distinguish four phases in learning processes with simulations: analysis, generation of hypotheses, testing of hypotheses, and evaluation [Duffield (1991)]. The alternation of generating and testing hypotheses seems obvious as a form of discovery learning. Therefore simulations, similar to hypertext systems, are viewed as forms of learning in which predominantly explorative learning can occur, in which the learner can actively construct his own knowledge base. Simulations virtually provoke an explanation through cognitive psychology and constructivist theories, although – as pointed out with Laurillard's remarks above– the distinction between scientific methodology and psychological processes of reasoning must be observed here. Simulations are therefore often employed for problem-solving processes training [Dörner (1976); Dörner/Krausig et al (1983); Scandura (1977)]. Vester (1984) uses them to foster »networked reasoning«. Among the most important learning objectives of simulations are: discovering and learning of systems concepts, rules and processes, and their recursive interaction, decision-making.

De Jong and Njoo (1992) observed 32 learning processes, two of the most important of which were: structuring new knowledge, and attaching new knowledge to previous knowledge, abilities that are reminiscent of Piaget's assimilation and accommodation processes. They differentiate learning processes into transformative processes (analysis, generation of hypotheses, testing, evaluation), and regulative processes (planning, verifying, observing). In experiments they observe that proficient learners had fewer problems with the explorative component: »This implies that a learning environment that asks this kind of behaviour explicitly from learners may produce major obstacles for the less proficient learners« (419). Other abilities may also play a part in the success of learners in problem-solving processes, like e.g. the ability of self-analysis and self-observation [Chi/Bassok (1989)].

SIMULATE

The above-mentioned study by de Jong and Njoo is one of several basic works from the EC project SIMULATE, probably the most comprehensive project on simulations treating this topic from a perspective of learning psychology, instructional design, as well as intelligent tutoring systems. In SIMULATE, so-called ISLE were to be developed (models constructed with SIMULATE). de Jong and Njoo view ISLE as IT systems, with the four traditional components: domain, student model, instruction strategies, interface. They identify four instructional functions: simulation models, learning objectives, explorative learning processes, and learner activity [s.a. Goodyear (1991)]. SIMULATE is supposed to support explorative learning, based on the method of Klahr and Dunbar (1988), the Theory of Scientific Discovery as Dual Search (SDDS).

van Joolingen and de Jong (1991) develop a »mock-up hypothesis scratchpad«, a software that is employed in a simulation program for error analysis in chemistry (4SEE is the simulation of a titration experiment) and serves to generate hypotheses. The scratchpads resulted in more space for hypotheses, especially before an experiment was carried out. The test persons formulated fewer hypotheses overall, because the tested hypotheses were usually well-formulated.

Goodyear (1992) studies human tutoring processes in employing simulation programs for dynamic models in the framework of the SIMULATE project. He reaches a similar conclusion as the one I have discussed with regard to the observations of Laurillard in the beginning of this chapter, i.e. that the cognitive demands of simulations are so high that one must offer »instructional support«. de Jong and Njoo (1992) distinguish between »directive support« and »non-directive support« (422), plus limitations in the simulation area. But as yet combinations of tutoring systems and simulations are merely concepts and plans: »As should be clear, however, creating a true SIMULATE authoring work bench lies beyond the reach of the present phase of the project« [Goodyear (1992). 424].

A »taxonomy« of simulations, rather a simple classification of possible uses in learning processes, is offered by Gredler (1986). He distinguishes: 1. structured questions and graphic simulations, 2. exercises with deliberate manipulation of variables, 3. more complex diagnosis tasks, 4. interactive simulations in groups. Wager, Polkinghorne et al (1992) carry out an analysis of simulations with the Gagné repertoire of learning results and learning events; Garson (1994) presents a list of 168 simulations and modelling programs and discusses the historical development of simulations in social sciences. Four models are distinguished here: equation systems, probability models, resource distribution models, and models of social processes. The most complex model is probably offered by Goodyear, Njoo et al (1991), who try their hand at a general theoretical framework for instruction through simulation.

Examples and Utilizability

In connection with intelligent tutoring systems, we had already several times hit on programs that were also simulations: The ITS STEAMER is a simulation model of part of a ship. IMTS (Intelligent Maintenance System) names STEAMER as its model [Towne/Munro (1992)]. The modelling system is combined with an intelligent tutoring system. IMTS offers two different editing modes for models: through the graphic object by way of the mouse (deep simulation) and through tables (surface simulation). *Smithtown* is an economic simulation, Voltaville a simulation in physics, as is Refract [Glaser/Schauble et al (1992)].

The *Live Labs* which Kay (1991) describes – e.g. the example of the *Apple Vivarium* program of an open school – in which the computer is not used as an alternative to reality but in order to facilitate learning, goes far beyond mere modelling. For one thing, this is because of the methods provided for the children for modelling fish, but especially because of the embedment in a social context and the entire environment. Thus, *Live Labs* become a paradigmatic example of the constructivist approach of learning environments.

Traditional areas of simulation are the simulation of equations in physics, and the simulation of machines, so-called virtual machines.

With NEWTON, Teodoro (1992) describes a simulation program for modelling laws of movement, with a user interface that is based on direct manipulation through the user of and with the program objects and tools. Virtual machines can be employed for personnel training in cases when the machines are not easily accessible (submarines), when their operation by beginners might be dangerous (aeroplanes), or too time-consuming (ships). Hriber (1993) reports on a simulation used for training submarine crews. The program simulates the engine room and controls.

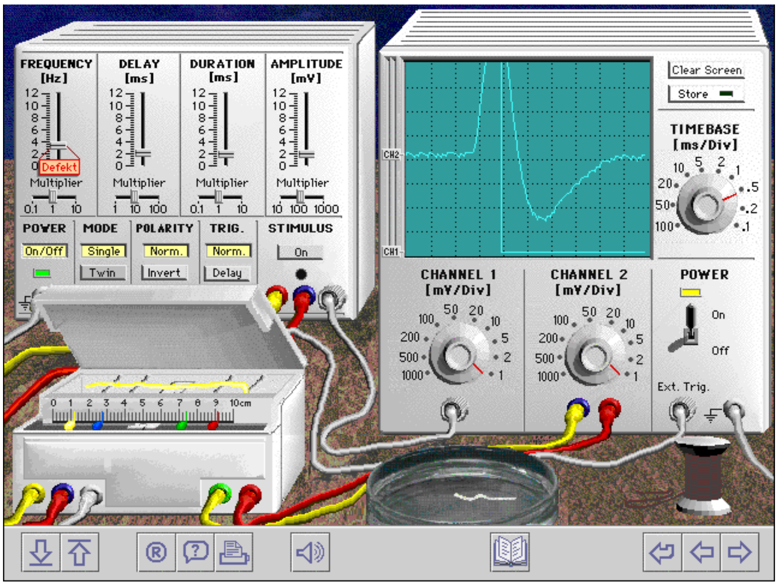
A virtual computer serves as instruction environment for a simulation in de Moura Guimarães and Dias (1992). The concept follows the instruction model and the elaboration model of Reigeluth and Stein (1983), as well as Keller's (1983) ARCS model. The model chooses a graphic scenario as its epitome, as instruction overlay, and starts in wide angle view. Further scenes add complexity or detail. The authors distinguish the individual learning phases following Reigeluth and Schwartz (1989), but favour open learning environments within this framework, for which reason they do not follow Reigeluth's ideas with regard to learner control.

Simulation and Laboratory

A special case of virtual machines and modelling of physics equation systems, and a current branch of simulations at the same time, is concerned with the modelling of laboratories, with the aim of replacing animal experiments with computer simulations. At the university of Marburg, the program *MacFrog*, winner of the German-Austrian Software Award, is used in practical training in physiology. It simulates a virtual laboratory for nerve measurements, and thus makes killing frogs superfluous. The program is distributed under the name *SimNerv* (Thieme Verlag). The topic of replacing animal experiments is discussed in Strauss and Kinzie (1991). They develop *The Interactive Frog Dis-*

section, a simulation with an interactive laser disc [s.a. Fawver (1990)].

FIG. 95
The Virtual Lab from *SimNerv*



Magin and Reizes (1990) discuss using simulations for laboratory experiments using the example of a simulation of a heat exchange model. Starting out from the reproach often directed at laboratory simulations that the analytically generated data do not correspond to real data, Magin and Reizes develop a method that imitates bad conditions of data collecting and measuring under realistic conditions [on simulations in laboratories s.a. Shacham/Cutlip (1988)].

Laboratory simulations are greatly facilitated by commercially available instruments. *LabView 2* (Laboratory Virtual Instrument Engineering Workbench) is a compiler with the help of which one can design instruments and analysis applications of high quality. *LabView* can deal with data collection, data analysis, data presentation, and control of instruments. It has a graphic user interface which can simulate original instruments and works with the method of direct manipulation. More than 130 instruments can be formed out of prefabricated modules from the library. Data flow, data presentation and data processing can be programmed with a programming language that is made up of icons. Data input is possible through GPIB, VXI, RS-232 or NuBus. The analysis functions comprise statistics, matrix algebra, and digital signal processing.

Evaluation of Simulations

I said earlier that simulation programs had come into being under the perspective of discovery learning and problem-solving. The evaluation of simulations should, to be consistent, refer to these dimensions as well. This is not at all the case, however. Most evaluation studies simply observe the increase of knowledge. Some studies find learning advantages in simulations [Ausubel/Novak et al (1978); Lesgold (1990); Linn (1990); Shulman/Keislar (1966); Katz/Ochs (1993) on *Smithtown*; Malakoff/Pincetl et al (1994)]; other studies do not find any particular advantages [Rivers/Vockell (1987); Shute/Glaser (1990); Swanson (1990); further references in de Jong/Njoo (1992), 413].

What seems to be particularly successful are attempts to replace animal experiments and anatomy courses with simulations. The highly charged question of which attitude to take towards animal experiments may have some part in this and obscure the pure learning value of the simulation. Kinzie, Strauss et al (1993) studied the learning processes in a simulation of animal experiments. The simulation was at least as successful as real animal experiments. Students who had been prepared for dissecting through the simulation executed the frog dissection more effectively than students who had not been prepared or prepared through a video [s.a. Kinzie (1993)]. Kinzie, Foss et al (1993) have compared two different programs for frog dissection with each other.

McCracken and Spurgeon (1991) describe an interactive 3D atlas of human and animal anatomy, with the help of which students can learn to understand the structure of the body and the behaviour of their own bodies in health and sickness. They suppose that the simulation could improve learning success in anatomy courses, or might even serve as a substitute for the anatomy course. Guy and Frisby (1992), on the other hand, find in an experiment with interactive laser discs for anatomy, in two anatomy courses with 473 students in all, that the learning success of students learning with the laser disc system was not significantly different from that of students attending the traditional anatomy course.

Other experiments reaching positive conclusions include active forms of learning in addition to the simulation, so that it is impossible to distinguish clearly which learning successes can be put down to the simulation and which to the activating methods. Some of these environments almost elevate this mixture of didactic models to the status of an agenda by classing it with constructivism. Lewis, Stern et al (1993) integrate real experiments and simulations in an electronic laboratory book. The topic is thermodynamics. The success of the experiment may be due to the combination of the different strategies, which allowed the students very active forms of working. Thornton (1992) introduces a computer supported laboratory at Tufts University. All 506 physics students had attended a course of lectures on kinematics. Nevertheless, there were high counts of mistakes in the posttesting. The error rates sank, drastically in part, with students who had visited the computer laboratory. Thornton puts this success down to the immediate connection of data input and graphic presentation of the data by the computer. Tinker and Thornton (1992) cite constructivism as their model and include three areas in their strategy: telecommunication, computer supported laboratories, and modelling programs.

Does the computer support problem-solving? In his overview of evaluation studies on simulations, Clark (1992) reaches a negative conclusion: »However, existing reviews are notable for their lack of compelling evidence for the hypothesis that instruction with computers makes any necessary psychological contribution to learning or to the transfer of what is learned during instruction […] To the contrary, evidence in these reviews of research seems to lend support to the claim that whatever learning advantage one can accomplish with computers can also be accomplished with other instructional media« (266ff.). We are not interested however in Clark's stereotypical question whether the computer as machine makes any contribution to learning, but in whether simulation as a method supports problem-solving.

If one looks at the exercises of Mayer (1992), however, who wants to test the hypothesis that the computer makes a contribution to problem-solving learning (199ff.), one can hardly do otherwise than agree with Clark. Whether these task cards appear on a computer screen or lie on the table in the form of printed index cards does not make any difference for the learner, unless the decisive variable is convenience, which is undoubtedly greater with printed cards. The same exercise, done directly in an interactive BASIC interpreter instead of a tutoring system, would have brought much more learning advantage to the students. Clark's criticism is clearly justified here. Mayer confuses hardware and software. He does indeed test the hypothesis whether the hardware makes a contribution to problem-solving, and that with a totally inappropriate software.

FIG. 96
Exercise from Mayer (1992)

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1. ASK THE OPERATOR FOR A NUMBER.
   PUT THAT NUMBER INTO BOX-B.
2. ASK THE OPERATOR FOR A NUMBER.
   PUT THAT NUMBER INTO BOX-R.
3. ADD THE NUMBERS FROM BOX-B AND BOX-R.
   PUT THE RESULT INTO BOX-K.
4. WRITE DOWN THE NUMBER FROM BOX-K.
5. THIS PROCEDURE STOPS HERE

IF THE INPUT LIST IS 5 9 7 12
WHAT IS THE OUTPUT OF THIS PROGRAM?
(A) 5  (B) 9  (C) 5 9 9 9 9 9  (D) 14
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Methodically controlled studies on the utilizability of simulations are far and few between up to now. Mandl, Gruber et al (1993) are concerned with the learning of simulation models, and in particular with the question whether students succeed in meaningfully employing and using the knowledge acquired in their studies in dealing with simulation models. They reach the conclusion that students of business sciences had less success with a simulation than students of education, that they were apparently not able to draw on the knowledge accumulated in their studies for practical decisions. Whether one may draw conclusions from this about the kind of knowledge mediated in the course of studies (e.g. too abstract) or the abilities required by the simulation (e.g. too practical), must be left open. Gräsel, Mandl et al (1992) describe the fostering of diagnostic reasoning through case-based computer learning programs in medicine. Similar results were found here.

Design Guidelines for Simulations

Thurman (1993) formulates the following guidelines for designing simulations (87):

Cognitive Structure

Make simulations perceptually appropriate for the level students have reached.
Make simulations correspond to actual systems.
Present only the essential system.
Use adequate detail.
Make the simulation logical to the student.
Make simulations inherently meaningful to students.

Cognitive and Metacognitive Strategies

Encourage strategies other than ‘practice’ or ‘rehearsal’.
Make concern for cognitive goals a very high priority.
Promote examination and employment of existing knowledge.
Support knowledge-refinement activities.

Automaticity of Cognitive Processes

Make consistencies overt.
Encourage active rather than passive participation.
Structure difficulty so as to ensure consistent success.
Strive for relatively stress-free conditions.
Isolate automatic components.
Do not invoke new response requirements until the previous one(s) have been automatized.

Affect

Shun extremely high or low levels of fidelity.
Provide clear goals.
Provide uncertain outcomes.
Vary the difficulty level within the simulation.
Use a motivational scoring system.
Provide a competitive situation.
Stimulate, satisfy, and sustain curiosity.

Again, I would rather let the design guidelines stand uncommented, since the appropriate stands beside the absurd, the impractical beside the practical, the specific next to the general, in short, it’s the little things that the problems hide in. My impression is that one can achieve much more with good examples than with general design guidelines.

CHAPTER 12

In the Land of Null Hypotheses

Pedagogical Myths About Computer Learning

I have adapted the title of this chapter from a phrase of Elshout's (1992), who in a comparative analysis of 22 studies on learning in pairs states that only two studies yielded a significant difference, of which two studies one favoured learning alone, while the other favoured learning in pairs: »Inspection of the signs of the nonsignificant differences does nothing to change the opinion that we are in Null-hypothesis country here. No proper meta-analysis will lead us out« (11). The kind of situation that Elshout found is not at all unusual. Most experimental comparative studies of teaching methods do not yield any significant results, and what few significant results there are contradict one another. Clark (1983) – in an overview of studies on learning with radio in the fifties, with television in the sixties, and with computers after that – also finds that »similar research questions have resulted in similar and ambiguous data. Media comparison studies, regardless of the media employed, tend to result in 'no significant difference' conclusions« (447). The reasons causing these meagre results are manifold:

- Most studies are so very bound up in the conditions of the time that their results are already out of date five years later; meta-analyses that compare thus historically conditioned evaluations must needs come to contradicting conclusions;
- Many studies compare methods that cannot be compared with each other, in a sometimes rather unfair methodical manner; control designs are fraught with such serious problems that the hope of reaching sounder statements in this way has up to now remained unfulfilled;
- Many studies are based on completely over-the-top hypotheses about the alleged effects of learning with computers which I have repeatedly called »pedagogical myths«.

Faced with this situation, Negroponte's (1995) position on evaluation research becomes understandable: »I have little respect for testing and evaluation in interface research. My argument, perhaps arrogant, is that if you have to test something carefully to see the difference it makes, then it is not making enough of a difference in the first place« (99). One does not even have to go as far as

Negroponte, who does not believe in evaluation on principle, to be able to see a certain justification in his arguments.

Historical Conditions of Evaluations

Carroll (1991) emphasizes the necessity of seeing research on computer learning and interfaces in its historical relativity and dependence on the state of technological development: »It is quite striking how in just a few years, major facts and concepts in HCI are quietly forgotten, abstracted, or merely revised [...] People were baffled by graphic icons and could not use the mouse to reliably point and select« (48). Carroll's comments are a politely understated criticism of the 'outdatability' of interface evaluations, the lack of vision in their authors, and the limited horizon of the questions pursued. I have already stressed elsewhere that one must view current developments with historical processes in mind, but also against a foil of a vision of future developments: »When we employ computers today, we always do it with a view to the future functions of computers that pupils and students may encounter in school, at university, or at work in 5 or 10 years« [Schulmeister (1993b)]. This statement is valid for the choice of concepts and facts to be studied as well as for usability research (we are dealing with differently socialized individuals every year).

There has been far too little historical research in order to be able to gauge how much the lives and culture of people have been changed by the computer's integration into society, and how people have adapted through use and gained experience: »Conceiving of user requirements and usability itself as processes unfolding in time gives us a more powerful model for defining and introducing technology« [Carroll (1991), 53]. One cannot do user-oriented evaluation research today using the same instruments as 10 years ago. Research on the phenomena of computer use and user interfaces, e.g. on the attention span, on the time dedicated to reading an electronic book, on the attraction and handling of certain user interfaces etc. becomes outdated much too quickly. Even studies overlooking a time span of only seven months call themselves »longitudinal studies« [Monty/Moran (1986)]. These studies are overtaken by technological development and increased use of the systems. In view of these rapid developments, historically unsound procedures can lead to misinterpretations. Carroll (1991) names an example for this: »Any explanation of 80-character record lengths that appeals only to synchronic rationales is simply wrong: today's 80-character records are caused by the physical properties of Hollorith cards used decades ago« (48).

What has become superfluous for example, are the many experiments on the following aspects of computer use [further examples in Carroll (1991)]:

- Virtually all studies of the quality of displays and the effect of CRT devices (cathode ray tubes) are outdated today, because the devices in this sector have been continually improved.
- One of the research questions studied most often is for example 'Is reading on a screen faster or slower than reading on paper?' Up until the 80s, there was general agreement that reading on a screen was slower than reading a book. Gould and Grischkowsky (1984) published a difference of 22%, found in experiments in a comparison of books with purely alphanumerical terminals. The authors revised their results themselves only three years later in a study that employed newer computers with white screens and black characters and anti-aliased fonts instead of the alphanumerical terminals [Gould/Alfaro et al (1987)].
- This kind of equipment is standard today. QuickDraw and PostScript have put an end to poor readability of typefaces on screens, anti-aliased fonts with backlit screens guarantee maximum readability, and sometimes typefaces with better contrast than insufficiently lit book pages. The example demonstrates how quickly research questions can become superfluous. A seriously intended overview of the many studies on screen display features like e.g. lower case vs. upper case, line spacing, colour, scrolling speed etc., which are mostly outdated today in view of the high performance of computers and software, can be found as late as in Mills and Weldon (1989).
- Such a judgement applies even to recent studies dealing with the »latest« research questions: Thus Christel (1994) compares the use of digitalized video in two hypermedia versions. In the first version, video was played with 30 frames per second, in the second version, only a still frame of the film was shown every 4 seconds. Users of the first version remembered 89% of the information, users of the second one only 71%. Christel concludes – and Nielsen (1995) seconds her conclusion (295) – that better graphics support learning with hypermedia. This may be the case, although the result depends on the example that is used. I can imagine studies in another context »proving« the exact opposite, namely that full screen films distract learners from the contents of the texts. Besides, the research question is clearly dictated by the limitations of current hardware configurations. In only a few years all user terminals will support full screen video with 25 fps or 30 fps, so that hardly a hypermedia designer will still think of replacing films with still frame sequences.
- Another much discussed problem of computer use is computer response times. For most computer activity, these are in a range today that is no longer felt to be perceptible by users, at least for tasks like entering text through the keyboard, reaction to mouse movements, calculations etc. Response times are only a problem today with data transfer in networks, screen redraw/refresh, manipulation of image databases, reading from CD-ROM, and opening and playing of video files. Studies dedicated to this thematic field usually come to negative conclusions about usability if the response times are too long. Thus Patterson and Egido (1987) find, for example, that users in faster systems (response time 3 sec.) call up 50% more pictures than in slow systems (response time 11 sec.). All computer users who in the past decade have themselves experienced how similar research questions were made redundant through technical development will know how to assess the results of such studies.

The like can be said for thousands of diploma theses and dissertations that compared memorizing of keyboard shortcuts vs. using menus, the interaction with menus vs. interaction through keyboard shortcuts, using the keyboard vs. using the mouse. How many online help systems have been studied with regard to their design, mostly under technical conditions no longer valid today? The list of such topics could be extended ad infinitum. I will allow myself a personal remark here: Strangely enough, there is one factor that has hardly changed – worldwide, we are still predominantly dealing with the standard of 7-bit systems, under DOS, Windows, and the Internet.

The reasons for the ongoing change in parameters are manifold:

Changing Parameters

New forms of interaction and new interfaces are being invented all the time, and influence and change user habits. It is to be expected that even more recent evaluation studies about the latest phenomena of the user interface will become obsolete again in a very short time, thus e.g. studies on »moving icons« (micons), or on the problem whether »picture icons« (picons) should stand alone or rather be provided with subtitles [Egido/ Patterson (1988)]. Use of keyboard and mouse will sooner or later be replaced by talking to the computer, and/or the tracking of eye movements [Starker/Bolt (1990)], and/ or the recognition of gestures, as Apple (1991) demonstrated in the film »Future Shock«.

More efficient hardware and more powerful graphics tools ensure higher quality in applications. In 1987, window systems were apparently still a problem for new users. Tombaugh, Lickorish et al (1987) found in a study that their test persons preferred the one window system over a multiple window system. But after only a short training period, multiple window systems proved to be superior. As late as 1989, Jonassen makes the mistake of writing an article on »Functions, Applications, and Design Guidelines for Multiple Window Environments«, in which he commits himself to positions in his design guidelines that are completely outdated today. Without any empirical verification, Jonassen claims that not all users profit from window systems, and builds his five recommendations on this premise, of which I will only quote the beginning of the second and fifth: »Limit the number of windows that may be opened by the user at any time« (192), and »Do not use overlapping windows in your displays« (193).

Nothing is more horrible than an arbitrary limitation of the number of windows that can be opened, a feature of MacWrite, MacPaint etc. whose usefulness I have never been able to grasp. I can also imagine many applications that would not at all get along with non-overlapping windows, especially in the age of the »Drag & Drop« technology that allows dragging objects from one window to another. It would be much more sensible to offer the user a choice, familiarization would do the rest: »The evolution of interfaces from the text-only displays of a few years ago to today's multitasking windowing environments with advanced graphics, animation, colour and iconic interfacing has familiarized both users and designers with many of the possibilities of the visual channel for communication« [Mayes (1992a), 6].

Guidelines like Jonassen's can have disastrous effects: Jonassen builds his guideline of nicely tiled windows being better than overlapping ones on nothing more than long cherished prejudice. But as late as 1992, the HyperHolmes Sherlock Holmes Encyclopedia switched from overlapping to tiled windows in version II [Instone/Teasley et al (1993)]. This step will soon prove to have been superfluous, when users have got used to overlapping window systems, or when entirely new techniques of screen presentation will let this problem be forgot.

The cost of hardware does not only sink in relation to income, but absolutely. Despite greater efficiency, the user must invest less today. That makes the decision for a more powerful processor, a larger hard disk, or a bigger display easier for many a user. Reisel and Shneiderman (1987) compare display sizes with regard to the question »Is Bigger Better? The Effect of Display Size on Program Reading«. The concise comment in Nielsen's (1995) annotated bibliography runs: »Bigger was better« (433). Today, larger displays no longer represent any particular cost factor. So this research question can be considered outdated as well. The question Taylor (1992) puts with regard to video integration, whether one should work with one or two displays, should be outdated, too, with the advent of digital video. In this case, software development has overtaken the hardware problem. Software technology has also overtaken the research question put in Pullinger, Maude et al (1987), which tricks might lead to advantages with regard to speed in reading texts on the screen: scrolling, jumping, or page-turning.

Today, many people have access to computers in school or at work. The consequence is that the novelty effect wears off and the effects of habitual use set in. Evaluators also notice this in their experiments. Thus Kulik and Kulik (1991), and Kulik, Bangert et al (1983) still state that the intensity of an effect measured in an experiment already wears off with the test persons after only four weeks. For people who have grown up with computers, this time span will probably become increasingly shorter. Gray (1990) wanted to find out in what ways mental text models corresponded to hypertext structure. The user's mental models were determined by reconstructing the information space with the help of diagrams: At first, users drew linear structures; with growing experience the diagrams grew less linear.

Thus it all depends on the stage of experience the learners included in experiments are in. The results may differ greatly because of this, or even contradict one another. We cannot foresee today how a generation used to multimedia from early childhood will react to the future possibilities of multimedia. So the question is what function our current ergonomics research has at all. One can state that today no scientist is interested in the research questions and results of studies done, say, in 1984! Or – might we even say – done before 1988?

Negroponte (1995) sees one of the reasons for the transitoriness of topics in the evaluators' attitude, who always ask alternatively whether one method (e.g. the light pen) is better than another (e.g. the data tablet): »The 'either/or' mentality was driven by the false belief that there was a universal 'best' solution for any given situation; it is false because people are different, situations change, and the circumstances of a particular interaction may be driven by the channel you have available. There is no best in interface design« (97).

Teaching experiments with learning software are also subject to rapid historical change. Studies around 1980 are mostly dedicated to the authoring systems that have practically vanished today. Even in 1984, there were hundreds of articles on authoring systems. Around 1987, the talk is almost exclusively of »courseware«. But there are of course – as always – exceptions: As late as 1986, one of the most prominent proponents of authoring systems from the Netherlands [Leiblum (1986)] collates an overview of authoring systems with the intention of making a plea for the future of these systems. Even today we find studies on paired associate learning. Thus e.g. Goldenberg and Turnure (1989) study the 'Transitions Between Short-term and Long-term Memory in Learning Meaningful Unrelated Paired Associates Using Computer-based Drills', and come to the following conclusions:

> »Two experiments in computer-based instructional design, modeled after the traditional flash card drill, investigated optimum queuing (scheduling) for reintroducing missed items in paired associate learning. Exp 1, with 129 11th and 12th graders, showed that the use of 2 intervening items (IVIs) resulted in significantly higher correct recall than the use of 3-6 IVIs. Using the results of Exp 1 as a constant for the 1st insertion gap, Exp 2 (n = 70) found that the use of 2 or 3 IVIs in a 2nd insertion gap resulted in higher recall than the use of 4-6 items. Results support the use of queued reminders during instruction to improve recall«.

Readers may judge for themselves whether they can make anything of this abstract of the article by Goldenberg and Turnure from the ERIC.

Methodology of Comparative Evaluations

Comparison of Methods and Control Design

Classic topics of comparative evaluations of teaching methods in the field of computer learning are »CAI versus lecture«, or »CAI versus book«. Let us look at some examples of such comparative evaluations:

Example 1 Garrud, Chapman et al (1993) evaluate the effectiveness of a CAL package on non-verbal communication. One group learned by using the software, the other attended a lecture course. The increase of knowledge was measured in a test one week later: the CAL group achieved better results in the test. The students' attitude was established through a survey: half of the test persons preferred software to lecture.

Example 2 Quade (1993) compared a CAI program with a hypertext on the topic of copyright and patent law. The introduction of learner control did not result in any difference of performance, and neither of the two methods (CAI vs. hypertext) proved to be superior to the other.

Example 3 Shiu and Smaldino (1993) compared computer program and reel-to-reel tape in learning Chinese. Textbook and tape were from the Beijing Language Institute in China, the computer program was by the authors. The students did better in the weeks in which the computer program was used, although no differences were found for some areas, e.g. listening and understanding. The software turned out to have the advantage in writing Chinese characters.

Example 4 Standish (1992) employed books on CD-ROM in at least three 15-minute sessions per week in addition to traditional reading lessons in order to improve the reading ability of second-year pupils in a mostly rural area of Delaware. A group of 20 pupils served as test group, and a group of 16 pupils as control group. Both groups were tested with regard to their reading ability before and after the experiment. Reading ability was analysed in a simple covariance analysis. Although no significant differences were found, the pupils' and teachers' comments seemed to indicate that the pupils' motivation to read the books on CD-ROM was very high.

Example 5 Wiebe and Martin (1994) compared a computer supported adventure game on geography with games that were not computer supported. They made a particular effort to control a possible Hawthorne effect. In posttesting, no significant differences with regard to remembering facts and attitude were found. They conclude from this that class games and activities are just as effective as computer games.

What do we get from these evaluation results? Basically, nothing but the obvious:

1. For one thing, the effect clearly depends on the learning objectives, i.e. the more clearly I define the learning objectives, the sooner differences will become apparent (Example 3).
2. The better a learning objective is suited to an interactive program, the sooner the program will gain an advantage (Example 1: learning objective nonverbal communication; Example 3: Chinese writing). I wonder, however, how performance in non-verbal communication can be evaluated in a test (Example 1).
3. The compared environments must be ideally prepared to be able to exercise their respective effects; if this is not the case, or if the environments are too similar, no differences will be found (Example 2).
4. Very often, independent of significant or non-significant results, extraordinarily positive attitudes for computer learning are found, which might point towards a novelty effect (Example 4).
5. If I control the Hawthorne effect, no significant differences will be found, at least not if I use one of the traditionally stronger pedagogical methods (Example 5), which have always been there, as we all know, and which should not be neglected because of the advent of computers.

Difficulties in generalizing statements from evaluations regularly tempt methodologists into calling for further differentiation and control in the methodical design. This can lead to the construction of utterly artificial learning environments, whose evidence thus loses its validity for real life situations [Schulmeister (1978), 7]. Unfortunately, the learners or students involved in such experiments as test persons are not highly motivated, critical, and independent enough to protest against rigid administration of CAL programs or artificial experiment setups.

One can slightly raise the demands on control design, the number of variables to be checked, and the number of methods employed [e.g. Knussen (1991)].

But such demands are difficult to meet. In their study of the main points of criticism in media research between 1950 and 1970, and between 1970 and the present, Yildiz and Atkins (1992) reach the conclusion that educationalists should give up trying to prove the efficiency of multimedia simulations in comparison to other technologies, and should instead concentrate their forces on researching the relations between learning tasks and learner characteristics [s.a. Yildiz/Atkins (1994)].

If one takes an occasional closer look at positive results of media comparison studies, one finds, in the words of Clark (1983), »that the treatments are confounded«. By »confounded«, Clark means that there is an effect ascribed to the medium here that is actually due to another, non-controlled variable, e.g. the didactic method employed: »it is the uncontrolled effects of novelty and instruction method which account for the existing evidence for the effects of various media on learning gains«. An indication of the novelty effect is the observation that the increase of learning diminishes once the students become familiar with the new medium. After eight weeks, the learning effect is only minimal. Since comparative studies frequently confuse medium and method, it seems necessary to Clark »to advice strongly against future media comparison research. Five decades of research suggest that there are no learning benefits to be gained from employing different media in instruction, regardless of their obviously attractive features or advertised superiority« (450).

The Difficulty of Typing, and False Labels

Considering the diversity of tested products and the high degree of differentiation in multimedia design, the question arises whether it is at all possible to infer anything about other products from a tested one. In other words, is it possible to transfer conclusions about the success of a Kiosk system to the usefulness of a hypertext textbook? Can we say at all, in the first place, when a multimedia program has been evaluated, that the type of program which the respective program belongs to has been evaluated? Or was this not rather an evaluation of a single program, so that is quite impossible to make generalized statements?

It is already so difficult to assign the respective software to a certain type that artefacts in evaluations are bound to result. Green (1991) suggests therefore: »We require two different evaluations: on the one hand, we need an evaluation of this design, whichever it may be, while on the other hand we need a recognition of the type of design and a broad characterization of its effects« (298). I think that Green's hope of getting a grip on the problem of artefacts through two different evaluations is a lost one. The wide variety in design and teaching methods leads to such a low degree of typability that it is impossible in the end to make generalized statements beyond the individual tested product.

False labelling unfortunately plays a serious role in evaluation research on computer learning. Under the cloak of modern scientific topics (e.g. »cognition research«), completely different, and partly antiquated questions are sometimes being studied (e.g. technical interfaces). The stern words of criticism that Green (1991) has addressed to the profession of Human-Computer Interface research (HCI) can be taken up unchanged for a criticism of evaluation research: »Most HCI evaluations and descriptions focus on the surface features: they treat rendering, not structure. Indeed, this goes so far that under the guise of 'cognitive modelling' HCI researchers have generated a crop of papers about how fast can the mouse be moved to a menu item or to a button, or how long it takes to enter a spreadsheet formula. This is HCI as target practice. Typically, no mention is made of parsing, conversational analysis, determinants of strategy, or many other central cognitive concepts« (298).

Extreme Differentiation of Variables

Schnotz's (1987) study comparing continuous and discontinuous texts comes to the conclusion that information is better absorbed in continuous texts than in discontinuous ones. Gordon, Gustavel et al (1988), likewise ascertain that retainment in reading short articles is poorer for hypertext versions than for linear versions of the same texts.

Schnotz's test was repeated by Mandl, Schnotz et al (1992). A hypertext was compared to a graphic representation of the text. The study no longer results in the conclusion now that A was better than B, but in the statement that hypertext was the medium more favourable to learners with better learning prerequisites. But the differentiation of the test setup according to learner variables and methods, and the interaction between them, still does not explain everything by half. New puzzles result. Why should learners with better learning prerequisites do less well in the method using printed text than those with less good learning prerequisites?

One possible explanation might be that this study controlled more variables than the earlier one, but once again not all the variables that play a part in the interactional structure. The problem of uncontrolled variables is widespread in evaluation studies. Pretest and posttest designs in evaluation are generally faced with the insurmountable hurdle that a multitude of variables impossible to control has an influence on the result [Mayes/Kibby et al (1990), 238].

The results of both studies are clearly dependent on the test persons' previous knowledge: the more previous knowledge there is, the more likely a non-linear assimilation of knowledge will be effective, and the more likely will it be possible for the test persons to develop mental models of understanding. The problem becomes more complex if one adds the assumption that learners do not always choose the form of learning that is suited to them [Kuhlen (1991), 197]. The need to get more precise results in evaluations necessarily leads to a demand for increasing the number of variables to be controlled. But even a high degree of differentiation in the variable sector will not solve the problem, because there will always be new variables which have not been controlled yet. Such a kind of differentiation would be the differential recording of the test persons' learning styles and strategies, for example.

But could such a variation of results with a methodical differentiation according to learning styles or learning strategies be verified at all? Billings and Cobb (1992) found no significant relation between learning styles (non-theoretical attitudes on the kind, time, and mode of learning) and learning success in their evaluation of an interactive laserdisc system, but they ascertained a positive attitude of learners to the medium itself (»comfort«) as the strongest predictor for learning success. This result is quite trivial, actually: students who are already familiar with the medium achieve better results in posttesting. This study is again contradicted by Larsen's (1992) study, who »proves« the exact opposite in an evaluation of a laserdisc system. He could not find any influence of the test persons' learning style and attitude to learning success.

In studies, it is not so much the careful statistical analyses that vary, but rather the learning theories used as points of reference, the quality of the employed learning programs, and the experiment conditions realized with those programs. When Larsen stresses that the employed laserdisc system allowed a lot of different types of learning behaviour even beneath the level that was controlled, then this is the exact reason for his non-significant results. It must be generally assumed that the majority of evaluations did not control the multitude of possibly relevant variables, in an endeavour to concentrate on just a few relations which were regarded as important.

Differentiation in the variable sector also results in a minimization of group sizes in control designs. Thus Hammond and Allinson (1989) used 80 paid students as test persons, but in a design which compared 10 groups. In this way they got group sizes of only eight people across which a variance analysis was calculated.

Hawthorne Effect

A similar conclusion as that of McKnight, Dillon et al (1991) about a study by Beeman, Anderson et al (1987), namely that a Hawthorne effect played a part here (112ff.), is reached by Janni Nielsen (1986) in a criticism of Papert's attempt to introduce LOGO in Brooklyn schools, and of Lawler's experiment to teach his own child to write with a computer in six months of close contact. Niemiec's and Walberg's (1987) meta-analysis ends with the observation that the Hawthorne effect had not been controlled in the studies which they subjected to a secondary analysis (34). Krendl's and Lieberman's (1988) meta-analysis, too, bemoans the fact that the most recent studies had not controlled the novelty effect despite earlier criticism (381). Another thing that speaks for the presence of novelty and Hawthorne effects is the fact that the effects are less marked in longer studies [Williams/Brown (1991), 29].

Kuhlen (1991) assembles a few factors that would have to be differentiated in evaluation studies:

»- the length of linear or non-linear learning materials;
- the nature of the subject matter […]
- the learning objectives aimed at […]
- the learning prerequisites […]
- the organization of the hypertext base […]
- the extent of the semantic specification of links […]
- availability of orientation help and metainformation […]
- availability of navigation help […]
- the extent of multimedia features;
- the flexibility of the user interface design« (203).

Levelling the Effect

With so many factors, no sensible design for experimental evaluation studies is possible any longer. And each new study will find new variables. Such a high degree of differentiation in the variable sector levels the effects of the other variables to be measured. The positivist ideal of the cumulative collection of knowledge through a progressive subdivision of the area of inquiry is not realistic therefore. And for the same reason, the demand made by McKnight/Dillon et al (1989) cannot be realized, either: »Future work should attempt to establish clearly the situations in which each general style of hypertext confers a positive advantage so that the potential of the medium can be reached« (18).

Yet one of the most important variables still has not come into view in all of the studies: the learning environment and the policy of the institution play a decisive part in the success of employing learning programs. Heywood-Everett (1991) reports case studies from five primary schools in which the connection between institution policy and the realized method of learning with computers becomes evident.

Usability of Test Person Statements

The ability of researched persons to make definite statements about themselves is decisive not only for ascertaining expert knowledge, but also for feedback in evaluation. But Nisbett and Wilson (1977) also point out what different kinds of theory formation and knowledge representation can occur in researched test persons. Evaluations that gain their data mostly from surveys of the test persons involved are problematic in general, because learners and students are not very good at making precise statements.

In Marchionini's (1988) study, which compared Grolier's Academic American Encyclopedia in book form and in electronic form, the test persons make statements like for example that the electronic form was faster, that the electronic version had more content etc., although exact measurements established that the test persons needed more time in the screen version, and although both versions had the exact same content. This study not only throws light on the problem of the usability of test person statements, but also illustrates another problematic point: The tested methods must be ideally prepared for and suited to their respective learning objective area. This was not the case in Marchionini's study:

- The hypertext version of the encyclopaedia was badly prepared. A part of the unfavourable judgements by test persons may be due to that circumstance.
- The hypertext version represented a new medium for the test persons and thus had a seductive effect on them, which may have caused them to arrive at the positively tinged statements.

Hawthorne Effect

Another phenomenon frequently noticed in evaluations of computer learning is demonstrated in the study by Brebner (1984). Brebner reports the evaluation of a computer supported learning program (CAI) with which the students were supposed to learn French. The results of the experiment show that the Drill & Practice exercises did not result in increased learning progress in comparison to traditional teaching. But Brebner reports that the learners developed a positive attitude towards computer aided instruction. Even stranger is the argument in the following case: In their study of a program on the orthography of Dutch verbs, Assink and van der Linden (1991) arrive at the conclusion that no effects of treatment variables could be observed. But all in all, they say, the software had proved effective. What are we supposed to think of this kind of argument? Learning success has not been improved by the experiment, but the students have a positive attitude towards the medium. Do learners not judge a medium by whether it helps them? Is this a novelty effect? Many studies on computer supported learning stress that the Hawthorne effect [Mayo (1933); Roethlisberger/Dickson (1939)] is one possible source responsible for positive attitudes of students [Bracey (1987)]. This effect also affects the test persons' ability to make objective statements.

Acceptance Research

Acceptance and attitude research is faced with the same problems as effect research. Attitudes depend on previous experience and environment. As long as students have not seen any multimedia environments, CAI programs get away with positive results. Results would probably turn out quite differently if the students had more multimedia experience. It makes no sense to restrict evaluation to problems of acceptance – why should I invest effort and money into the CAI program if it does not improve learning results but produces a positive attitude? And even if the learning result were improved by the program, the result might be a short-lived one: the next experiment, perhaps this time with a hypermedia system, might again result in a positive attitude, and would thus point towards the fact that a positive attitude towards the system only appears with novices and will quickly fade again as soon as they have a wider standard of comparison. Evaluation research encounters similar difficulties in trying to establish factors for willingness and ability to innovate. The trivial nature of some results can hardly be surpassed: thus Krendl (1986), for example, reports the critical factors that determine the acceptance of the new technologies in schools: (1) whether there is an institution for the existing media, and (2) whether that institution is able to integrate the new technologies into its organizational structure.

Opinion polls depend on environment factors and experience (s.a. my comments in the section on learner control). Thus Jones and McCormac (1992) have e.g. searched for empirical evidence in two experiments in order to settle the question whether user opinions could be used for an evaluation of computer aided learning (CAL) in a training course for nurses. In the first experiment, 61 first year students were introduced to the employment of computers in nursing for two hours, and were then asked to assess eight features of the computer on a scale of 7. In the second experiment, they surveyed second year students who had not received a special introduction to the employment of computers in nursing. The results demonstrated that the test persons' opinions about the computers were influenced by previous experience with computers, and were not related to features of the system actually present.

Students »may not be the best judges of what instruction they need, how much instruction [they need], when to seek instruction, and what to attend to in an instructional segment« [Canelos/Baker et al (1986), 67]. This is already known from interrogations of students on lectures vs. group work in the 60ies. The contradictory statements of students on the advantages of certain methods can be put down to experience and the dominance of the methods in their environment. But comparative studies based on student statements often neglect to consider the test persons' previous experience and the context dependence of their opinions, although »interrogated subjects are likely to be ignorant about the range of possible alternatives, a fact that severely restricts the generalizability of their statements« [Schulmeister (1978), 4].

At best, the established statements will be valid, but their validity will be geographically or temporally limited because of the dependence on context. One would have to research at the same time whether attitudes change, and whether long-term studies are therefore necessary. Such questions are seldom put. Krendl and Broihier (1992) studied the nature of the reactions of 339 pupils in fourth to tenth grade (53,4% girls and 46,6% boys) to computers over a period of three years. Changes in the test persons' perceptions were studied using three dependent variables (preference, learning progress, and subjectively experienced degree of difficulty). The results clearly point towards the effectiveness of the novelty effect. The test persons' decision for a preference for the computer diminished significantly over those three years, as did their belief in being able to learn with this technology. The assessment of the degree of difficulty, on the other hand, remained stable, and both sex and age reacted significantly to all three dependent variables. Older pupils showed a more sceptical attitude towards computer technology than younger ones, boys had a more positive attitude than girls. These relations did not change over the course of three years. The results of this study support criticism of the methodological limitations of studies on computer effects.

Meta-Analyses on Computer Learning

Meta-analyses of evaluation studies are secondary analyses that allow a more precise judgement of the intended effect's size, because they transform the original data into percentages/percentiles of the standard deviation for the increase of points in final tests. In comparing teaching methods, a typical advantage effect of less than half the standard deviation is found: »In the case of computer-based instruction studies in college environments, for example, this advantage translates as an increase from the 50th to the 66th percentile on final examinations in a variety of courses« [Clark/Craig (1992), 21].

One of the first meta-analyses that calculated compatible effect values for learning success with the help of statistical methods is the study by Hartley (1977) on 51 studies on individualized instruction. She found that computer aided instruction did increase learning success, but that this effect was not as pronounced as the effect created by the employment of peer teaching or tutor groups.

Kulik, Kulik et al (1979) report in a meta-analysis of 75 studies on the 'Keller-Plan-Modell' [Keller's Personalized System of Instruction, PSI, Keller (1968)] that these studies demonstrated rather high success rates on average (namely .5 SD), much higher rates than other studies on individualized instruction and similarly high ones as in those for computer aided instruction. While Clark (1983) still believes: »A compelling hypothesis to explain this similarity might be that most computerized instruction is merely the presentation of PI or PSI via a computer« (448), I think that this rather points towards the fact that in the end any change of traditional teaching will have an effect. As long as efforts to modify the traditional social forms and to reform instruction can be observed, this is apparently rewarded by learners.

The Teacher's Role

Kulik, Kulik et al (1980) found more than 500 studies comparing traditional media to computer aided instruction. They established a difference of .5 standard deviations, which however decreased to .13 in those experiments in which the same teacher instructed both test group and control group. This is clear evidence of the important role the teacher has in the acceptance and effect of the introduction of new teaching methods, and perhaps also evidence of how small the difference between methods is in general if one fails to consider the teacher as variable.

Bangert, Kulik et al (1983) replicated Hartley's (1977) meta-analysis, with even lower results (.10 SD). While Hartley still believed to be able to prove a greater effect for individualized instruction at least for higher education, Bangert, Kulik et al arrive at substantially lower values for employment in higher education as well. Their conclusion is sobering: »Individualized systems of secondary school teaching have not met the great hopes they once raised [...] Individualized systems promised to revolutionize teaching and to revitalize learning. Twenty-five years of evaluation studies show that instead of producing such dramatic effects, individualized systems at the secondary level yield results that are much the same as those from conventional teaching« (150).

In a further study, Kulik, Bangert et al (1983) believe to be able to ascertain definite advantages for CBI (.32 standard deviation), and positive attitudes in test persons. But the analysed studies include only four that cover a longer period of time, and their long-term effects turned out to be non-significant. Clark (1985) points out that positive results must be measured over a longer period of time in order to eliminate the novelty effect. Kulik, Bangert and Kulik observe that studies published in journals reported more marked effects (.17 higher) than unpublished dissertations. While they explain this difference with the argument that the quality of studies by recognized scientists was higher than that of other authors, Clark (1983) supposes that this difference is simply due to the acceptance policy of the scientific journals' editorial teams.

Confounding Medium and Method

Positive effects of a new method decrease if the same teacher is involved in all methods being compared [Clark (1985)]. If the methods being compared are presented by different teachers, on the other hand, one can no longer decide »whether to attribute the advantage to the medium or to the differences between content and method and the media being compared« [Clark (1983), 448]. Clark even calls the stated time saving in learning with computers an artefact, because of the higher effort necessary for developing the new medium (449). Clark sums up his criticism of the Kuliks' meta-analyses in the accusation that medium and method had been confounded here. Further instalments of the debate between the Kuliks and Clark can be found in Clark (1985), Kulik, Kulik et al (1985), and Clark (1985b).

Rosenberg (1990) tackles the meta-analyses of Kulik, Kulik et al (1980) and Kulik, Bangert et al (1983) on the employment of CAI systems in school in detail. I will have to quote the full text of her criticism in order to make clear what gross mistakes the criticized authors have made:

> »Typically, results are reported as follows:
> In one paper, 54 of the 59 studies collected statistically significant data on

> exam performance. Of these 54, 13 favored CAI and one favored conventional instruction. The conclusion is that CAI improves exam performance.
> Here is another way to present the same data:
> Of the 59 studies, 22% favored CAI, 2% favored conventional instruction, and 76% favored neither or were not statistically significant. The conclusion is that nothing is demonstrated about the effect of CAI on exam performance.
> Here is more data on which the papers' conclusions are based:
> Exam performance: In the second paper 48% favored CAI, 4% favored conventional instruction, and 76% favored neither.
> Withdrawal rated (reported on in only one paper): 3% favored CAI, 2% favored conventional instruction, and 95% favored neither or were not statistically significant.
> Students' attitudes toward subject matter: In one paper, 3% favored subjects taught with CAI, and 97% favored neither or were not statistically significant. In the other paper, 20% favored CAI, and 80% favored neither« (187).

Rosenberg points out that university teachers consider the majority of evaluated applications not acceptable in any case (188).

What is interesting for our discussion are the meta-analyses of interactive laserdisc technology, the forerunner of modern multimedia programs.

Kearsley and Frost (1985) review several evaluation studies on laserdisc programs. Mostly positive effects are reported, especially time saving in learning. Most studies come from U.S. Army training: »To summarize, the available evidence suggests that videodisc is a highly effective instructional medium across all types of educational and training applications« (9).

Bosco (1986), on the other hand, states a draw in his meta-analysis of 28 evaluations on interactive laserdiscs: »In essence, sometimes interactive video appeared to be more effective than the comparison instruction, and sometimes it did no better than the comparison form of instruction« (15). He explains the contradictory result with the circumstance that the variance of effect is due to the multitude and varying quality of the applications.

Bosco compares this to evaluating textbooks: here again, he says, there is no categorical answer to the question whether a textbook is suitable for teaching and learning, it depends on the instruction's learning objectives and the quality of the books. For this very reason, Bosco criticizes that in 19 out of 29 studies included in the secondary study, little or no information about the nature of the interactive program was supplied: »When information on the specifics of the instruction is lacking, it is impossible to look for clues which might explain differences in findings on effectiveness« (15). While the supporters assign positive effects to the medium as such, the situation looks quite different to a critic: »Yet, it would be difficult to rule out the strong possibility that the variable which produced a learning gain was not media, but the method variable many of us refer to as 'interactivity'« [Clark/Craig (1992), 25]. This instruction method offers a higher level of activity, which may explain the results. But increased interactivity can in principle be offered in different media, including the personal medium 'teacher'.

Braden and Shaw (1987) researched evaluation studies on the employment of computers with deaf children in a meta-analysis. Of 287 titles, 162 described employing computers in an educational setting. In a table sorted according to categories, the following distribution resulted: higher education (120), psychological studies (12), school (30). Only 9% of studies on university education gave data for the method's efficiency. Although most studies made a claim to positive results, the degree of success of computer aided instruction seemed to be inversely proportional to methodological precision. Methodically well realized studies rather arrived at the conclusion that computer aided instruction could not prove any particular advantages.

Niemiec and Walberg (1987) analyse 16 of such secondary or meta-analyses, and come to the following conclusion: »From our synthesis, CAI, with an average effect size of .41 is moderate and about as effective as tutoring or adaptive education« (35). Roblyer's, Casting's et al (1988) meta-analysis of more than 200 studies on computer aided instruction reaches a positive result as well, but the learning gain again ranges around less than .3 standard deviation.

Five years after Bosco's study, McNeil and Nelson (1991) also carried out a meta-analysis of studies on interactive laserdiscs. They applied relatively strict criteria to the studies that were to be included in the meta-analysis. Of 367 studies, only 63 met their criteria. 79 variables were coded, of which only 25 were interpreted, however. In addition, they distinguished between comparative evaluations and instructional design evaluations. 30 publications were dissertations, master's theses, or government studies, which, as already stated, report slightly less marked effects. The authors paint a discriminating picture: methods introduced in addition to conventional instruction were more effective than those that replaced the traditional method. In general, interactive video seemed to have advantages for both individual teachers and groups (effectiveness .53). Studies that compared an interactive laserdisc with the employment of video tapes did not yield any differences, however. Some studies pointed towards the decisive role of the teacher. But McNeil and Nelson make a point of stressing the shortcomings of their meta-analysis, which could not control many of the relevant variables, and for many of the interesting variables could not even find data in the studies: »Variables such as the nature of instructional content, environmental factors, instructional methods, features of the learning materials, and certainly the characteristics of the learner undoubtedly influence achievement to varying degrees. This information is rarely provided in sufficient detail to be coded and analyzed« (5).

A study carried out by Jolicoeur and Berger (1986) makes clear on what shaky ground such meta-analyses are. Using ERIC, and roughly 200 surveys, they established the small number of 47 empirical evaluation studies that were possible candidates for their purposes. After a more thorough check for suitability, precisely two studies remained which they could have included in a meta-analysis. The reason for most studies having to be excluded was that more than one program was employed in the experiments described. Jolicoeur and Berger conclude from this that meaningful meta-analyses are not possible on the basis of existing data.

Krendl and Lieberman (1988) analyse evaluation studies considering several different aspects: They are interested in statements on learning effects, cognitive effects, motivation and self-assessment, and environmental factors. Their interest is mostly methodological. Nevertheless, some interesting insights result for our purpose. In their overview of LOGO experiments, they find that on the one hand the statements on effectiveness, especially LOGO's effect on cognitive concept formation, are inconsistent, while it had turned out on the other hand that the role of the teacher was the decisive element in the effectiveness of instruction and the acquisition of transferable reasoning abilities, and that the social environment was an important factor for the learners' motivation.

Elshout (1992) compares two meta-analyses of evaluation studies that came out in the same year (1989) and that both arrive at similar positive results: »There are two conclusions to be drawn that are of special interest to our own discussion. The first is that after student related factors – such as prior achievement, intelligence, specific interests, etc. – have been taken into account, only a relatively small part of the total variance in achievement can be credited to all educational factors taken together, say 20 to 30 percent. That makes it understandable that educational factors taken one at a time, if they make a difference, typically have an effect, expressed as a point bi-serial correlation, not larger than .20« (xx).

Clark and Craig (1992) sum up the long succession of evaluation studies and meta-analyses on laserdiscs and multimedia: »1) multiple media, including videodisc technology, are not the factors that influence learning; 2) the measured learning gains in studies of the instructional uses of multiple media are most likely due to instructional methods (such as interactivity) that can be used with a variety of single and multiple media; 3) the aspects of dual coding theory which formed the basis for early multi-media studies have not been supported by subsequent research; and 4) future multi-media and interactive videodisc research should focus on the economic benefits (cost and learning time advantages) of new technology« (19).

Hasebrook (1995) analyses meta-analyses and individual studies on learning with computers from several points of view: combination of text and picture, animations in multimedia, imparting of structural knowledge, interpretation and self-control of the learning process. His conclusion is: »It is not possible to make general statements about the learning effect of multimedia on the basis of current knowledge. The comparison and critical evaluation of existing studies and overviews has shown that multimedia systems have the potential to improve learning performance. Nevertheless, the overwhelming majority of currently employed multimedia systems has little or no positive effect on learning performance« (101). Once more, it is in the details that the problems lie. Only with a sufficient differentiation of didactic interventions and a consideration of the overall conditions under which they are employed can effects of multimedia learning environments be demonstrated. But with a high degree of differentiation, effects are levelled again.

Studies dedicated to learning programming were initially based on the assumption that one had discovered a new general ability with programming, the ability for general information processing, a »Latin of the 20th century«, so to speak. After a look at relevant studies, Clark (1992) comment on this assumption is: »The original hope that the learning of computer programming would sharpen general thinking and problem-solving skills seems unsupported. Thus, there seems to be a lack of compelling evidence of 'domain-general' transfer which is attributable to computer programming expertise« (267ff.). The transfer quality of programming has still not been proved, he says, programming remains domain-specific (as, incidentally, Latin was as well). When a transfer was shown, the computer was not a necessary medium, and transfer ability was trained with special didactic methods. Clark calls the confusion of human information processing with programming an inadmissible reification of a metaphor for cognition.

The confusion accusation also applies to studies specially dedicated to problem-solving by way of simulations [Clark (1992)]. An extensive overview of evaluations and meta-analyses on authoring systems is offered by Shlechter (1988). He, too, arrives at the conclusion: »positive instructional effects found for CBI might be traceable to factors other than the medium« (335).

Rating Procedure

Apart from the already mentioned Educational Testing Service there are two other institutions in the USA that continuously evaluate learning software: EPIE (Educational Products Information Exchange), and Microsift. In 1983, EPIE listed 4.500 programs in 24 fields [Bialo/Erickson (1985) 228]:

Mathematics	26.3%
Science	15.7%
Reading	11.8%
Language Arts	10.6%
Social Studies	6.2%
Foreign Language	4.6%
Computer Language	2.4%
The Arts	2.2%
Early Childhood	2.2%
Business Education	1.9%
Logic/Problem Solving	1.1%
Computer Literacy	0.9%
Other	14.1%

One can see clearly that, at least at that time, learning programs were most widely spread in the subjects mathematics and natural science. As for type of software, there were mostly Drill & Practice programs and tutorials (229):

Drill & Practice	49.4%
Tutorial	18.9%
Educational Game	12.3%

Simulation	5.4%
Other	14.0%

Bialo and Erickson (1985) analysed 163 courseware programs by EPIE with regard to objectives, subject matter, methods, and evaluation, in order to see whether there were certain discernible trends across courseware types and subjects. They found that only a third of the programs had well-defined learning objectives, and concluded that most of the programs did not at all make efficient use of the possibilities of the computer: "Much of this software is poorly designed instructionally and is no more than electronic workbooks. Those involved in commercial courseware development […] often-times lack expertise with regard to the instructional issues involved in designing educationally sound courseware." (233) The results of recent surveys are not so very different from the reported insights as one would wish. An HIS study on the employment of new media in university teaching, conducted in collaboration with myself [Lewin/Heublein et al (1996a); Lewin/Heublein et al (1996b)], in which about 1.000 projects were covered, for one thing shows a similar distribution with regard to subjects as the EPIE study, and for another thing makes clear that new media are mostly used for presentations in lectures and the Internet, and that the share of learning programs especially developed for teaching is relatively small.

Field of Study	**absolute**	**%**	**Univ.**	**Techn. Col-lege**
Language/Culture	175	18	24	7
Law	24	3	4	1
Business Science	148	15	16	13
Sozialwiss.	60	6	6	7
Mathem./Science	355	36	35	33
Medicine	41	4	5	-
Agronomy / Forestry / Die-tetics	28	3	3	-
Engineering	279	29	18	59
Arts	45	5	4	6

Teaching / Learning Aid	**Absolut**	**Prozent**
Presentation	41	38
Total	**109**	**100**

Teaching / Learning Aid	Absolut	Prozent
Online Script	18	17
Hypertext	4	4
Tele-Teaching	2	2
Introductory Learning Programs	4	4
Advanced Learning Programs	24	22
Language Learning	4	4
Multimedia	2	2
Experimental Games	5	5
Virtual Education	2	2
Discovery Learning	2	2
Total	**109**	**100**

Jolicoeur and Berger (1986) have compared the two institutions' evaluations in a meta-analysis, although the evaluation criteria of the two institutions overlapped only partly. The evaluations of 82 programs could be included: »The correlation was only .33, significant different from zero ($p< .001$) but far below acceptable levels of reliability for alternate measures of the same concept« (9). A special comparison of only the design criteria for 29 programs, which were much more similar for both institutions, yielded a correlation of only .22, a value that is not significant different from zero: »The unfortunate implication of these data is that there is little evidence for convergent validity and no evidence for discriminant validity of ratings in typical software reviews«. The obvious question arises whether rating scales as evaluation method have any significance at all, if the construct validity of these methods can be called into doubt so clearly. For the reasons discussed in this section, I cannot share the authors' conclusion, who see an alternative to ratings in experimental control designs.

It seems much more sensible to give an evaluation of the contents in free textual form. The American association of pedagogues, which deals with the employment of software in instruction, EDUCOM/NCRIPTAL, attempts a different approach to software evaluation. Bangert-Drowns and Kozma (1989) describe the evaluation procedures and criteria of this organization, which gives a yearly award to the programs judged to be excellent. Following EDUCOM, the Federal Republic of Germany for the first time established the German Higher Education Software Award in 1990 (German-Austrian Higher Education Software Award from 1991) through a similar evaluation procedure. As member of the jury, I also took part in the development of the evaluation criteria. From 1994, this enterprise became the European Academic Software Award (EASA) through the participation of several European countries. The evaluation procedures are significantly different from the rating procedure in that it was possible to discuss the evaluation criteria among the jury, and agree upon a consensus after long debates. Once the consensual procedure is given up, however (e.g. due to lack of time or because of the effort involved), the evaluation criteria will be reduced to a rating procedure.

Fundamental Methodological Objections

1. The typability of the applications is low: it is individual cases that are being tested, not the program type of an application. Consequently, even conclusions from similar studies are impossible to generalize.
2. The experimental situations are artificial in many ways: research questions are tested in artificial situations which do not tell anything about a possible extrapolation to real learning situations.
3. The experiments are dependent on the institutional and interactional context: test conditions in comparative studies are thus not comparable, although they should be.
4. The results of different methods cannot be compared using the same posttesting procedure. Hammond and Allinson (1989) consciously use two different posttesting setups in order to examine the effect on study behaviour in reading differently prepared versions of a hypertext, a multiple-choice test and a questionnaire. According to their results, the posttesting method influences the students' manner of approaching the learning program.
5. The number of actually intervening variables approaches the infinite, while only a restricted probe is included in the study: »Our failure to account for much of the variance in the models by independent variables analyzed in the study indicates that cognitive achievement from IV is influenced by a myriad of variables that are difficult or impossible to account for in a single meta-analysis« [McNeil/Nelson (1991), 5]. This statement is valid not only for meta-analysis, but for all comparative setups.
6. If the decisive variable for learning success is the teacher and not the tested system, then the teacher's effort ensures success, confirming the hypothesis: »the potential benefits of CBI [...] all hinge upon the dedication, persistence, and ability of good teachers and courseware developers« [Kearsley/Hunter et al (1983a), 94]. If this hypothesis is correct, one can only agree with Rosenberg's (1990) conclusion: »Of course, if there were enough dedicated, persistent, able teachers and course developers, and a social commitment to support them, would anyone be interested in ITSs?« (189).
7. It has been claimed, rightly in my opinion, that – if any positive effects of interactive multimedia technologies on learning can be demonstrated at all – this is due to the designers' efforts and the methods realized by them, not to the technology as such [Clark (1983); Clark (1986); Clark/Craig (1992)].

8. We absolutely need a differentiation according to learners. Studies differentiating in this way are very rare [e.g. Cordell (1991)]. But if learner variables were incorporated into the studies to a greater degree, they still could not achieve more generalizable statements about »the« teacher, and it is quite impossible to test the entire potential variance of learners.
9. Experiments in the field of educational studies are strongly influenced by the Hawthorne effect [McKnight/Dillon et al (1991), Bracey (1987)].

There are thousands of reports by teachers on experiments in school, mostly with inadequate setups, but with sophisticated controlled test designs in part. Almost all of them report a learning increase in the end. Again and again, one is tempted as reader, if the subject is right, if the study agrees with one's own prejudices, to cite such results [thus Ferguson (1992), 40]. But we do not need any of those »careful studies of the impact of … on …«. What we need are teachers and lecturers who are highly motivated, who can fill their pupils and students with enthusiasm, and programs that are interesting, thrilling, highly interactive, and aesthetically designed.

The Impossibility of Evaluating Multimedia

Pedagogical Myths

Two influential hypotheses seem to reign over evaluation studies on computer learning, the »Meeting Place« hypothesis, and the »Melting Pot« hypothesis: »Two tacit assumptions, the additive assumption and the multiplicative assumption, seem to govern past and present enthusiasms for the use of multiple media in instruction and training« [Clark/Craig (1992), 19]. The implied meaning is that the media incorporated into multimedia either complement one another by adding up, or else form a new whole. I have not been able to find sufficient evidence for either hypothesis in evaluation studies.

Further differentiation is also called for with regard to the studies' objectives: thus some experiments intend to supplement traditional instruction with the new media [e.g. Farmer (1993)], while other experiments want to replace traditional methods with new media. The evaluations I have reported do not offer any insights into these strategies either. Frau, Midoro et al (1992) wonder »Do Hypermedia Systems Really Enhance Learning?« That was my question, too, when I started this book. And I am still of the opinion that one should answer this question with yes, only not under any conditions, and not for all the programs and types of programs discussed in this book.

Most studies aim at proving that the learning method has an effect on the students' cognitive learning. Only few succeed in doing that; many studies show that no differences result in the field of cognitive learning objectives, but instead in variables like enthusiasm, affective attitude towards computer learning, or, as in the study by Mevarech and Ben-Artzi (1987), in the attitude towards mathematics phobia.

Differentiation According to Learning Styles

One of this book's main hypotheses, reaching all the way from the definition of multimedia in the introductory chapter, by way of the discussion of instructional design and intelligent tutoring systems, up to hypertext and hypermedia systems, was the thesis that one had to succeed in differentiating the effects of learning processes according to individual styles and strategies of learning. In an experiment with postgraduate students in information science and the hypertext example '1992 – The single European Market', Ellis, Ford et al (1993) analysed the test persons with regard to their learning styles before the experiment, using two scales (field independence / dependence, and holistic learners / serial learners). The authors found that holistic learners preferred maps, while serial learners preferred the index; serial learners retained more and achieved higher results in the knowledge test, while holistic learners tried to give more answers and had less problems with admitting that they did not know something. Field independent students read more documents than field dependent ones. This seems to support the demand for more differentiation according to learning style constructs.

A second experiment of the same authors with the hypertext application 'Food & Wine' for students of dietetics could not reproduce these results, however. Only one non-significant distinction for field independence / dependence was found. The authors' conclusion is this: »Learning and cognitive styles have been demonstrated to be a significant component of individual behaviour within the hypertext environment. This component is not, however, rigid and inflexible, and does not necessarily enforce a particular style of usage upon a particular individual« (17). When different navigation options are offered, the differences between learners seem to be levelled. Marrison and Frick (1994) did not find any significant differences, either. Even the learning style variables always assumed as relevant do not seem to be valid everywhere and under any conditions. Might they turn out in the end to be an pedagogical myth? Other studies show, on the other hand, that it apparently does not matter at all what kind of instruction method or learning program I offer to highly motivated and capable students. They learn equally well under any conditions, whereas weaker students rather profit from more strongly directed learning situations [Mevarech (1993)]. Should I not simply bury my educational ideals in that case, and stick to expository instruction? I am convinced that what we have here, again, is another twisted research question and confusion of hypothesis with test instruments.

Interactivity – the Decisive Factor?

There is one other hypothesis I have formulated more than once for which I have not found much empirical evidence: the thesis that the degree of interaction was responsible for the attractiveness of programs for young people, and was thus a good criterion for distinguishing good from bad programs. I have even based the classification of program types and the organization of this book on that hypothesis. One of the few studies on this topic is Fletcher's (1989) meta-analysis of studies on interactive video. In 47 studies, he found three types of software: tutorial, simulation, and combinations of the two. Most studies (24) came from military training, 14 from the academic field. He arrived at a positive judgement on interactive video, which demonstrated an advantage of .50 standard deviation over traditional instruction, an effect that seemed to be greater than in comparable studies on computer supported instruction. Tutorials proved to be more effective than simulations. In five of the studies, Fletcher was able to pursue the relation between success and interactivity: »The more the interactive features of IVD technology were used, the more effective the resulting instruction« (373). This seems to support my hypothesis, at least in part, although the established ranking order of tutorial and simulation is already food for scepticism. But what are we supposed to think when Palmiter and Elkerton (1993) compare a highly interactive environment with a text-only environment, and have to state that the highly interactive environment proved to be superior in training, but that the result was reversed only seven days later? If it does not make any difference at all whether I offer multimedia or lectures [Miller/Jackson (1985); Hudson/Holland (1992)], then the obvious differences that keep being observed must be due to something else. And I cannot be content with a result saying that there was no difference in the learning result, but that time had been saved with the interactive laserdisc [Leonard 1992]. That could turn out to be quite different by tomorrow.

The experiment of Gräsel, Mandl et al (1994) comes a little closer to answering these questions. They analysed the learning processes of 34 students of medicine with the multimedia program THYROIDEA, which follows a constructivist concept. The students were offered an expert commentary and coaching on demand. They found that the students used the interactive parts of the program intensively, »particularly the option of articulating their own actions« (229), but they also found »that the use of interaction options is not automatically reflected in the acquisition of application-oriented knowledge « (230). Nevertheless, the authors noted clear evidence for the effectiveness of the two active forms of learning, individual articulation and coaching: »This might support the demand of constructivist instruction theorists [sic!] that learning environments should stimulate learners to a high degree of activity. For these two interaction options are also the ones that most easily stimulate learners to interpret their knowledge in relation to their previous knowledge, and apply it to the problem«. There are many kinds of interaction, and the differences are not made clear in all evaluations. But if the learning environment as a whole is stimulating, as constructivists demand, the differences are more likely to become plausible.

Formative Evaluation as Alternative?

It is only logical that constructivism should insist on participatory forms of evaluation [Heller (1991)]. Forms of formative evaluation are much more appropriate to such complex environments like the ones constructivists aim for [Reeves (1992); Byrum (1992)]. Formative evaluation cannot resolve all doubts about evaluation research as well, yet it yields quality insights into what is happening. But for a comparison of instruction methods or program types, it is just as useless as the experimental method. An overview of formative evaluation methods will be found in Savenye (1992). One of the few examples of formative evaluation is the collection of six »Case Studies in Computer Aided Learning« by Blomeyer and Martin (1991). The advantages of formative evaluation have become clear with studies that observed the children's learning progress over a period of two years. One observation may demonstrate the discrepancy between learning with PLATO and classroom teaching: the children like to learn with programs, but apparently for a different reason than that PLATO helps them to learn mathematics, because many exercises are arranged in the form of games [Stake (1991), 87]. Other observations concern changes in the children's attitude towards a disliked subject, the function of computers for weak pupils, the role of motivational factors, and the teachers more or less identified with the long-term experiment. A formative evaluation employing video recordings will be found in Blissett and Atkins (1993), who noted the children's activities on the screen every five seconds. I do not want to report this study in full, but merely point out one specific detail: the problem in this experiment evidently was not to motivate the children into learning, but to catch learners who slipped below the desired level. They conclude from this that »the full potential of this IV disc would not be realized without a teacher available« (38).

As sobering as the results of the evaluations are, they are a consequence of their own methodology. Not analysed were the reasons for young people's voluntary use of programs, the growing interest of young people in interactive environments, the pleasure in learning with animations and games, and the lack of pleasure in formal instruction. There is no alternative to a playful exploration of programs, comparative evaluations would be quite useless here. There is no teacher available during leisure time, no textbook will entice as a pleasurable afternoon activity – but the computer offers attractions: there is incidental and implicit learning there that has never been measured by an evaluator. The results of evaluation studies on scientifically designed learning programs are sobering: we are left with the hope that the motivation to learn which is sooner sparked by playful programs, and those designed with a lot of imagination, can be transferred to other subject matters that today are still disliked by pupils and students.

CHAPTER 13

A Plea for the Imagination

The Fascination of the Feasible

Edutainment

In judging possible functions and uses of hypermedia learning technology, it is important not to let oneself be led by today's insufficient state of technology, but to see this in perspective as a historically dependent status. But it is just as important to have visions and not remain tied to today's status in assessing future uses of hypermedia in instruction. In saying visions, I am not, however, referring to those unimaginative contributions collected in the reader edited by Nickerson and Zodhiates (1988) carrying the demanding title »Technology in Education: Looking Toward 2020«. The best multimedia examples are those that grew out of a pleasure in games, and some commercial applications called Edutainment, not the pedagogically motivated, »scientific« learning programs. Science should take up this challenge!

In a panel discussion at the European Conference on Hypertext, Gerald Nelson dared take up the question »How Should Hypermedia Authoring Systems for Computer Aided Instruction Look Like?« in a completely unscientific way [Rizk/Streitz et al (1990)]. I take pleasure in quoting his statement here because it is completely unpretentious and makes clear which real problems hypermedia developers have to tackle:

> »In a fit of naivete, I decided to develop my own CAI package to teach principles of economics to a large number of students working on their own in many different computer laboratories (see the AECONIntro demonstration).
>
> Some lessons I learned
>
> - get lucky and hire a student who combines knowledge of educational techniques with excellent HyperCard programming skills
> - don't try to be fancy. Someone will find a way to break your stack
> - test your software again and again and again; or learn how to deal with wiry students
> - lead the horse to water and force him to drink'; tell students exactly how to use the software and how it will improve their grades
> - be prepared to sacrifice your career
> - work at a university with good computer facilities and other faculty with interest in computer-aided instruction.« (341)

Empowerment

Perhaps the discussion of the various theoretical approaches is less relevant than many advocates of these schools think. We need a teacher and an incredibly attractive learning program, and an opportunity to let students communicate with each other. Interesting learning processes and phenomenal learning success will be the result. What more do we want? We can pursue this as long as the Hawthorne effect and thus success last. To put it with Euler and Twardy (1988): »Whatever the Orientation, Creativity is Demanded«. If we could just bring a little variation into the business, we might even achieve a longer curiosity effect. Computer games have a fascinating effect on many. The idea to utilize this motivation effect for learning environments has brought about the term Edutainment. Brown (1985), speaking of »empowering learning environments«, sketches the idea of a robotics game, in which the user can program the movements and actions of the figures in the game instead of guiding them directly. Such a game was launched on the market only a short time after. Gentner (1992) also appreciates the motivational effects that computer games have on young people, and analyses their attractiveness and the mechanism of their effect: »Of course, I'm not the first person to argue for the importance of motivation in learning. The concept of empowerment has lately become popular in the United States. I'm not very fond of the word, but I think the idea is important« (228). A decision for one of the schools of thought discussed in this book is perhaps less relevant than the designers' attitude towards living and learning, that which Gentner calls »empowerment«. With the right attitude, creative solutions that motivate to learning can be found on the market.

Imagination

On this note, Euler (1990) describes Apple's »Introduction to the Macintosh«, of which many Macintosh users have fond memories, as a humorous example of CAL: »CAL has specific possibilities, whose use in design depends on the author's qualities, however. It is only the author's educational imagination that can mediate subject matters in a more graphic, motivating and activating way to the individual learner than they might be mediated by other learning methods« (187). I agree wholeheartedly with his exclamation: »When all is said and done, CAL is only in good hands with those educationalists who are good pedagogues without a computer as well!« (188)

Scientific schools of thought always make assumptions about the character of the learners they intend to deal with, and always use different theorems of learning psychology for this purpose. McKnight, Dillon et al (1991) rightly point out that it is not a matter of mirroring a specific student, but of finding the common denominator of all students: »If we look at the intellectual activities of the majority of school, college and university learners, they involve the storage, retrieval and manipulation of information. Despite what educationalists say about personal development, self-actualisation, intrinsic motivation and all the other fine phrases, the fact is that students at all levels are presented with existing knowledge in a variety of forms (books, articles, lectures), they make notes on the information (either directly as marginalia or separately in a notebook), they reorganise the information for essays and so forth« (121). I can also agree with their conclusion with regard to the method that might support this common denominator, although one might presumably name a few other methods as well: »Hypertext offers a computer-based information environment which could support all these activities« (121). The alternative to individualization would then be a learning environment as wide and open as possible, in which learners could provide their own adaptation work.

Pragmatics

One can achieve acceptable solutions with small effort. With such thoughts in mind, Bork (1987) analyses three small physics program with regard to their suitability for instruction. He admits that many learning programs deal with natural user interaction in only a very limited way, and thus cannot react individually to each student. He also concedes that artificial intelligence applications are much too costly in development and demand too expensive hardware. A pragmatic approach is therefore advisable in dealing with decisions about the software to be used in learning and teaching: »Our current approach is based on the concept of utilizing, as much as possible, what already exists and is established in significant quantity in the educational marketplace« [Romiszowski/Chang (1992), 111].

Pedagogics is so simple really! If only one allowed teachers to find the optimal method and the program most convincing to themselves, which they can best justify before their students and pupils. One teacher is popular because he can demonstrate experiments with enthusiasm, another teacher is excellent in motivating students to do individual projects, a third is only accepted by pupils if he presents carefully prepared exercises. Winn (1989) makes a plea for a reciprocal recognition of teachers' and computers' respective strengths and weaknesses: »After all, teachers are good at things our delivery technologies are not very much good at, and vice versa« (44).

Infotainment

Stebler, Reusser et al (1994) formulate the ideal demands on the schools and universities of tomorrow: »We must create learning opportunities that take up the students' previous knowledge, take into account the situation dependence of reasoning, and plan learning as a self-controlled process of building up knowledge in learning and researching communities. We need interactive learning/teaching environments« (232). Romiszowski and Chang (1992) describe an experiment in which students maintained a communication tutor-guided by *HyperCard* over a network for one semester. The description of the experiment, which belongs in the area of communicative learning activities in electronic networks for which Infotainment has become the accepted term, should stimulate all educationalists, and the authors' conclusion should provide food for thought:

> »All of the approaches described were successful in considerably diminishing the problem of 'structure' and 'control'. A final 'test discussion' across all topics in a one semester long seminar-based course revealed that all students had a similar view of the topics that were discussed and the relationships that existed between the topics. They did not agree, however, on their viewpoints in relation to these topics. This is as should be: the structure of a complex domain was successfully communicated, without necessarily conditioning the participants to one set

> of opinions (the professor's) on how the domain should be interpreted and used« (116).

Employing the concept of communicative learning environments demands the utmost acceptance and tolerance on the teacher's part in order to realize the wealth of learning processes embedded in this approach.

Edutainment & Infotainment

Functional and Educational Advantages of Multimedia

The true advantages of multimedia learning environments comprise first of all Alan Kay's (1991) four criteria: interactivity, a wealth of information, multiple perspectives, and the simulation of dynamic models:

- »The first benefit is great interactivity«.
- »A second value is the ability of the computers to become any and all existing media«.
- »Third, and more important, information can be presented from many different perspectives«.
- »Fourth, the heart of computing is building a dynamic model of an idea through simulation« (106ff.).

On careful examination, I think I have more or less observed Kay's four commandments:

The central importance of interactivity to learning is one of the few characteristics of multimedia computer learning that has run all the way through the book and made it even through the evaluation section.

Future user interfaces will probably even further enhance the attractiveness of computer learning, with the computer that speaks and »understands« language perhaps only a temporary stage of development or an application for special purposes (Dictaphone; learners who are weak at reading; interactive instruction in foreign languages) [but see Leong (1992); Hillinger (1992); Pontecorvo/Zucchermaglio (1991)]. Buxton (1990) sees gestures as the »natural« language of interaction with computers: »We have argued strongly for designers to adopt a mentality that considers nonverbal gestural modes of interaction as falling within the domain of natural languages« (415). In the test system »VirtualStudio«, Kurtenbach and Hulteen (1990) outline possibilities for utilizing gestures as a future computer interface. Many contributions in Bichsel's (1995) conference proceedings are dedicated to gesture recognition (not to be confused with handwriting recognition, which is sometimes also referred to by that term).

Parents and teachers of children who frequently use computers increasingly give accounts of distinct progress in the English language, and put this down to dealing with American programs and texts. These are not valid data, of course, but it seems a plausible consequence of motivated play. Americans, Englishmen, and Australians can of course profit less from this circumstance.

The attractiveness of Edutainment will be even further enhanced in the future through the development of hardware and software technology: The technical stage of integration achieved for pictures and text, or text and sounds, has now been achieved for digitalized films as well in. Technical options have been developed for digital films that are not possible for analog video: the development of three-dimensional films which are navigable in all directions. These are films that – building on ideas from the *Aspen Movie Map* – have knowledge of the pictures to the right, left, above, below, and diagonal positions for each frame of the film, and can immediately branch to those views at the respective mouse movement. Apple Computer published sample films as early as 1992. In 1995, Apple then released *QuickTimeVR* to developers, a system extension allowing such surrogate trips, or that which – in contrast to »virtual reality« – I have already called »augmented reality«.

Besides all the factors mentioned – the enthusiastic teacher, the interesting program, the contextuality of the learning environment, the highly interactive communication – the decisive element in the success of computer supported learning systems is finally the GUI, the graphical user interface, in which aesthetics, simplicity and interactivity are combined.

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