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Research on Instruction in Multimedia Learning Environments: Design and Effects

Lehr-Lernforschung mit multimedialen Lernumgebungen

This paper describes the design of problem-based learning environments in which multimedia are used. The authors assume that presenting problems to students stimulates the development of knowledge, skills and attitudes. Three types of problems are distinguished, problems of categorization, interpretation and design, the solution of which result in different cognitive constructs. The types of problems are described and the instructional-design rules for learning to solve these types of problems are specified. The paper then discusses different research projects in which students learn to solve categorization and design problems.
Attention is paid to representation of reality in a multimedia environment. In the research projects the effectiveness and efficiency of the instructional designs in multimedia learning environments are tested.
The paper finally addresses the usefulness of multimedia learning environments for learning to solve the different types of problems.

Ausgehend von der Annahme, daß der Prozeß des Problemlösens die Entwicklung von Wissen, Fertigkeiten und Einstellungen fördert, sollen im folgenden problemorientierte Lernumgebungen, in denen Multimedia zum Einsatz kommt, beschrieben werden.
Die Autoren unterscheiden drei Problemtypen: kategoriale, interpretative und gestaltende, deren Lösung unterschiedlicher kognitiver Strategien bedarf. Weiterhin werden die Anforderungen, die an ein Instruktionsdesign gestellt werden, das Problemlösen-Lernen ermöglichen soll, spezifiziert.
In verschiedenen Forschungsprojekten, die das Lösen von kategorialen und gestaltenden Problemen zum Inhalt haben, werden Wirkung und Leistungsfähigkeit des Instruktionsdesigns getestet, mit besonderem Blick auf die Repräsentation von Wirklichkeit in multimedialen Lernumgebungen.
Abschließend soll die Nützlichkeit multimedialer Lernumgebungen in bezug auf die menschliche Problemlösekompetenz aufgezeigt werden.

1. Problem solving and problem-based learning environments

The work of the authors on instructional design is directed towards the design of problem-based learning environments, which can be integrated with existing curricula or used independently (Dijkstra & Van Merriënboer, 1997; Dijkstra, 1997).

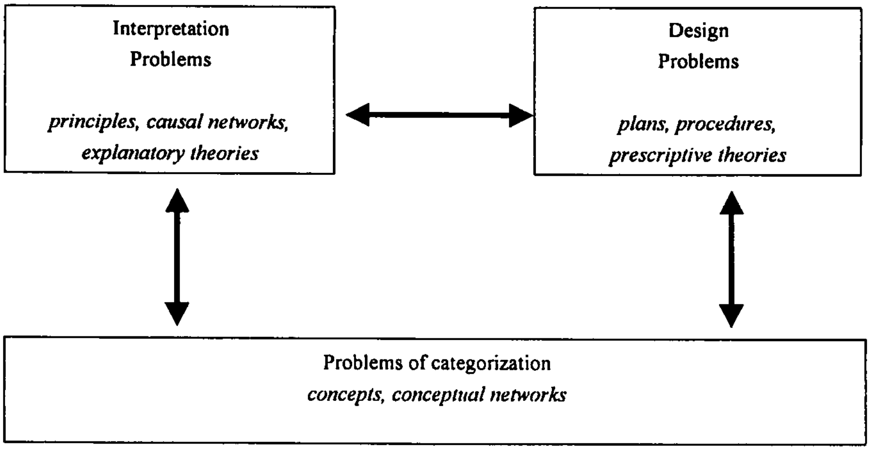
A problem is a question which cannot be answered immediately. A procedure to solve it has to be applied or developed. For problem solving, the problem space, which is either reality or a representation of it, must be explored. Features and phenomena must be observed by the senses, hypotheses are developed and tested. Problem-based learning environments encourage the activity of the students and stimulate the development of knowledge.

The authors assume that the students are intrinsically motivated to learn. They can study the learning material individually to reach a personal goal or study it by obligation at school. The authors also assume that the designers of learning material know how much consensus there is about the content, and how well- or ill-structured the problems are which need to be solved. The learning material is developed for multimedia learning environments, used for studying the effectiveness and efficiency of the instructional designs implemented in these environments, and also for studying the specific effects made possible with this technology. Learning in such environments also has the advantage of reaching a sufficient level of experimental control. The authors suppose that problem solving is an activity requiring exploration of the reality, observation of regularities and hypotheses about the behavior of the reality. The investigation, which requires expert guidance, leads to experiences with the reality. Exploring the reality leads to the careful perception of objects and their structure, to categorization of objects and to the development of models and the formulation of hypotheses on why things change. Problem-solving is a complex activity, which needs and leads to reflection on the reality, and, if this can be verbalized, to the development or construction of knowledge.

Three types of problems are distinguished: (a) problems of categorization, (b) problems of interpretation, and (c) problems of design. These types and how they relate to each offer are shown in Figure 1. Learning to solve a category of problems results in both the development of knowledge and simultaneously the learning and practice of the problem-solving procedure. This is a sequence of steps that should lead to the solution or the goal to be reached. If the problem-solving procedure of a category of problems is a fixed sequence of steps (operations) which, if correctly applied, always will result in a correct solution, then the procedure is labeled an algorithm. After considerable practice, such a procedure can lead to the development of a skill.

In case of problems of categorization objects or entities have to be assigned to categories. The knowledge that develops is labeled a concept or conceptual rule, both of which are class or relational concepts. If objects have to be assigned to more categories between which relationships can exist then the knowledge is labeled conceptual networks. Concepts and conceptual networks are basic elements in human cognitive structures and are considered to be the vehicles of thought. Concepts make it more easy to describe the huge number of objects perceived by individuals. Their features are used in order to categorize them, and these features must be perceived by the senses. They

Figure 1:
Three types of problems and their relationships



can be relevant for categorization, which means that they are comprised in the conceptual rule. Other features are irrelevant or non-defining. Both relevant and irrelevant features can contribute to the categorization of objects. This issue will be made clear later in this article. The features that are comprised in the conceptual rule have to be identified. The steps to solve a categorization problem therefore is labeled the identification algorithm.

In the case of problems of interpretation an attempt is made to interpret the change of objects. This can be done by hypothesizing on an event in the past that caused the change, or by formulating an hypothesis and based on that, making a prediction about an event which will take place in the future. The problem-solving activity starts with observing phenomena, decoding it, finding a regularity in the information, inducing an hypothesis and making predictions as to what will happen. An experiment (an operation to generate phenomena) can then take place. Under controlled conditions it may be possible to find a regularity and test the prediction. The knowledge resulting from problems of interpretation is in the form of hypotheses, principles (laws) and explanatory theories. The problem-solving procedures are the procedures used in the experiments e.g. measurement of phenomena under data yielding controlled conditions. They are processed by mathematical procedures. Often it is necessary to design special apparatuses in order to generate the phenomena.

In case of problems of design, the ultimate result is an artefact, something constructed by a person. As described at the beginning of this article, in solving a problem of design two phases are distinguished: design and realization. In the first phase, a sketch is made of an object which must be created.

Here the designer draws up a list of requirements and forms ideas about the appearance of the object. For solving the problem the designer must take into account existing rules concerning design, and work within the constraints of the available material and according with the relevant empirical laws. For example, in designing a seeworthy yacht there are several rules of design which must be followed in order that the yacht conforms to "normal proportions". The application of these rules guarantee that the yacht will sail safely and will look good. The formulation of this rules of proportion is sometimes based on centuries of experience. One example of a rule concerning the design of a yacht is "the ballast weight equals .3 to .5 of the total weight". As well as the constraints afforded by a program of requirements, the yacht designers must work within the constraints of the rules of normal proportions and apply them all. Further rules to be applied are produced by the materials available for use, and hydrodynamical knowledge. Once the sketch is ready and accepted by the client, the designer embarks on the first drawing and drawing of construction to be used by the shipyard's personnel. The plan of construction is drawn up, after which the materials can be ordered and delivered. Finally the personnel whose skills are in differing areas may begin and complete the process of construction.

The purpose in solving a problem of design is that the object to be made has to fulfill a specific human need. Sometimes an object is designed but never actually created, because the clients reject the design. Different kinds of problems of design can be distinguished, but to the authors' knowledge there is no definite categorization that can be organized into a kind of taxonomy. Within the area of applied sciences several groups of designers exist, such as architects, mechanical engineers, and so on. But solving a problem of programming is also an example of solving a problem of design. Town and country planning are examples of solving problems of design. Learning how to hold a type of conversation involves solving a socio-communicative problem of design. An example will be given later in this article.

As can be seen from the links in Figure 1 it is possible to distinguish a problem category individually but often they appear in combination. For solving a problem of design it is often necessary to apply the knowledge that came from solving an problem of interpretation. If an artifact is made, it may have unexpected effects, resulting in a change of interpretation. This happened, for example, when it became clear that the behavioristic rules of programming an instruction did not conform to different categories of learning. These at least speeded up the change to a cognitivist approach. Finally solving a problem of design results in an artifact that as such may lead to new (sub)categories of objects. For example a recent type of car such as a "motor home" is a new subcategory of cars. A problem of interpretation always concerns concrete or assumed objects, for example plants and insects, molecules and atoms, whose changes are the subjects of research to test new hypothesis. Sometimes an object can only be categorized after many changes. Some plants, for example, can be categorized based on the features of their seeds, in which case biologists must wait until the seeds have formed.

The problems of the three categories are further distinguished in terms of well- and ill-structuredness, complexity, generality and abstractness. Dijkstra and Van Merriënboer give further descriptions. A well-structured problem is a problem whose solution can only be right or wrong. The solution of an ill-structured problem however, can only be better or worse. The degree of complexity of a problem is related to the amount of knowledge involved, and to the number of operations required for the solution. The degree of generality is related to all objects of a category or taxonomy of categories, whereas the degree of abstractness entails considering objects and their relationships, looking away from their empirical existence.

2. Research on instruction and learning in multimedia learning environments

2.1 Multimedia

The final developments in computer technology which have taken place in the 1990s that will affect and already have influenced education, are the digitalization of sound and motion pictures, and the large scale linking of computers in global networks. The first development enriches the represented reality and makes it possible to interact with it in multimedia settings. The concept of multimedia in education refers to learning materials which utilize different senses simultaneously. This already has a long tradition in education. In interactive media presentations, both visual and auditory forms of information are stored digitally in the same format. This means that they can be mixed for use in instruction. Simultaneous presentation in interactive multimedia presentations is therefore easily realized (Romiszowski, 1997).

2.2 Problem-solving, instructional design and multimedia learning environments

For learning to solve the three categories of problems, overlapping and different instructional-design rules apply.

For all the categories, whether they appear individually or in combination, the students are required to solve the problem, which means that they have to construct the knowledge and develop the procedure to solve it. This will be indicated in advance in a goal description. If the problem-solving procedure is generally applied and necessary for public functioning then - in elementary or secondary education - the students are required to automate the procedure. If the problem-solving procedure is executed by skilled personnel or by a group of specialists, then the students are also required to automate the procedures.

For the design of instruction, the next step is to make a decision on how to approach the reality or how to make a representation of the reality to which the knowledge applies. One must also explain how the students can operate on it. The reality itself is the primary source of information, but it has so many features that students can easily get confused. A mediated instruction (e.g. textbook, video) as a secondary source of information can better organize the information, but there is a danger that students cannot adequately imagine the reality and relate the information to it which would allow it to become useful, functional knowledge. Dijkstra and Van Merriënboer describe some factors that will be taken into account for the choice of the (re)presentation and related to this the choice of a medium: (a) the perceptibility of objects (e.g. bacteria, planets, historic monuments in foreign countries), (b) the experimentation necessary in order to come out with evidence for the structure of reality (e.g. matter, molecule, atom), (c) the duration of a process and (d) the risk of damage versus personal safety. They also make clear that economic feasibility influences the decision on how to approach the reality. Moreover the solution of instruction in and on the reality itself depends on whether the knowledge and skills will be used for functioning in a profession or as prerequisite knowledge for later training. They suppose that the perception and manipulation of the real world will in general lead to better retention, understanding and use of knowledge and skills.

A further step is to communicate with the students and describe the problems to be solved. This may include presenting some information and asking questions to which the students must answer. Sometimes it is possible to directly ask questions. For the categories of problems some general instructions apply which are directly related to the problems involved. For learning to solve problems of categorization, the students should be able to observe and manipulate the objects to be categorized and compare these to find similarities and differences. For learning to solve problems of interpretation the students should have the opportunity to produce phenomena in order to induce regularities in the data and find relationships within it. For learning to solve problems of design the students should be able to draw up the requirements, imagine the object to be designed and produced, then make a sketch of it and plan its formation. It is necessary throughout the problem-solving process and also on its completion, to have coaching by an expert.

If it is not possible to approach the reality itself a medium is necessary to represent it. If it is possible to approach and manipulate the reality, it is often also necessary to use a medium. The problem category provides indications for the choice of a medium (Dijkstra, 1998). In case of problems of categorization objects have to be categorized. In this case for the determination of concrete living objects (e.g. in biology and physiology) that are subject to change, a multimedia environment in which video and sound are used often is a good representation of the reality. For example, for the determination of birds and mammals, for understanding the metamorphosis of insects, and so on, video is the best medium. For learning to diagnose patients and for treatment, videos of patients can be used.

For processes that have to be inferred from the change of objects the experiment probably is most useful for learning, but if this is not possible animations and simulations are useful to understand the interpretations.

The use of video has particular advantages, e.g. for showing how socio-communicative problems can be solved, or what steps can be taken in many problems of construction.

The use of a multimedia learning environment in which video and sound are used that can be computer controlled became operational in the 1980s and became known as "interactive video". Videotape was first used, followed by videodisks. In the beginning of the 1990s, the movie material became stored on cd-rom or on disks of local server computers. The authors used these technical developments to represent the reality for purpose of instruction and for studying the effectiveness of instructional-design models and rules.

Two examples of research on teaching models for learning to categorize objects are discussed. In the first example the use of picture books and computer-based instruction is explored, in the second the use of interactive video, using a video disk. One example of solving social communicative problems using a multimedia environment is described and discussed.

2.3 Research on categorization and concept learning

Knowledge that develops as a result of solving a categorization problem is labeled conceptual knowledge and the procedure of categorizing new objects into the same category is named the identification algorithm. For learning to categorize, a sample of the objects has to be available or a representation of the objects needs to be shown. The students observe and inspect the objects to find similarities and differences. They may discover which attributes are defining, but often they are first informed which attributes are defining and included in the conceptual rule.

The development of conceptual knowledge has been studied throughout this century and the results of studying have always been used for developing and improving instructional-design models. For studying the effect of instructional-design variables for the development of concepts the authors used the concept teaching model that was developed by Tennyson and Cocchiarella (1986). This model is a extension of an earlier model by Merrill and Tennyson (1977). The new model was strongly influenced by the concept learning theory of Rosch (1978), a theory that contributed to the rediscovery of constructivism in the United States of America (Lakov, 1987). The model that is used for studying the effect of instructional variables in research projects by Ranzijn (1990, 1991) and by Gulmans (1998) is shown in Table 1.

Table 1:
Instructional Design Strategies for concept Teaching[1)]

Attribute Characteristics	Relational structure: Successive	Relational structure: Coordinate
Constant dimensions	Strategy 1	Strategy 2
	Label and definition Best example Expository examples (successive presentation) Interrogatory examples (optional) Embedded refreshment	Labels and definition Best examples Expository examples (simultaneous presentation) Interrogatory examples Attribute elaboration Embedded refreshment
Variable dimensions	Strategy 3	Strategy 4
	Label and definition Context (problem domain) Best example Expository examples (successive presentation) Interrogatory examples Strategy information Embedded refreshment	Labels and definition Context (problem domain) Best examples Expository examples (simultaneous presentation) Interrogatory examples Attribute elaboration Strategy information Embedded refreshment

The model comprises two basic components of instructional design: (a) the content structure of a domain of information and (b) the organization of instructional-design rules directly related to specific cognitive processes in the development of concepts.

For describing the content, the relational structure between concepts must first be distinguished. There are two basic relationships: successive and coordinate. A successive concept has clearly discriminable defining and variable attributes (e.g. a rectangle). A coordinate concept has multiple critical and variable attributes. These are often overlapping in objects of subcategories (e.g. the concept chair with many subcategories: Biedermaier, Bauhaus). Secondly the variability of the attributes has to be determined. If the critical attributes remain stable across contexts the concepts are labeled constant-dimension concepts (e.g. a chair). If they vary across contexts they are labeled variable-dimension concepts (e.g. competitor-companion, who can be the same person in different contexts).

The instructional-design rules are based on the content structure and attribute characteristics. Tennyson and Cocchiarella distinguished three sets of rules which are related to cognitive processes. The first set of rules are relevant for storage and retrieval of conceptual knowledge. The label and the definition of a concept seem to facilitate the connection between prerequisite knowledge and the new concepts. In case of variable-dimension concepts the presentation of a context contributes to finding the relationship with the existing knowledge. Embedded refreshment may help to retrieve necessary prerequisite knowledge for the development of new knowledge.

The second set of instructional-design rules comprise best example and expository example. The presentation of a best example corresponds with the concept of prototype. This is the most representative member of a category. It has the most attributes in common with the other members of the category. If the instructor decides which objects will be presented the best examples come first. Expository examples are objects that are members of the category. The use of expository examples will foster the development of conceptual knowledge by comparing and contrasting these examples. It also will start the development of the identification algorithm. The third set of instructional-design rules primarily enhance the learning and practice of the identification algorithm or problem-solving procedure. However in case of error the conceptual knowledge may also be changed. The rules comprise interrogatory examples, strategy information and attribute elaboration. Interrogatory examples are simply problems of categorization. The information given should be compared with that of the best example and expository examples. This can only happen if the attributes of the best example are stored as a prototype in memory. The correspondence between the number of attributes of different objects can be diminished gradually. It is supposed that this instruction will enhance the development of the procedural knowledge necessary for the generalization and discrimination skills. Procedural strategy information will further support this development. Attribute elaboration is distinguished in attribute prompting and attribute feedback. The first contributes to the development of conceptual knowledge, the second also strengthens the procedure.

The decision about the content structure precedes the application of the three sets of instructional-design rules. The content structure as such also is of importance for the instructional design. Tennyson and Cocchiarella suggest that for the acquisition of a coordinate concept the objects of the subcategories should be shown simultaneously, whereas the objects which are members of successive concept classes should be presented successively. Ranzijn (1991) studied whether the simultaneous presentation of coordinate concepts contributed to the effectiveness of the instruction. In his research he used members of natural categories as objects. For the coordinate concepts he used examples of two families of conifers "Thuja" and "Chamaecyparis". Their description and identification algoritm show substantial overlap and members of each concept class resemble each other closely at the defining characteristics. The concepts of "windflower" and "insectflower" were used as successive concepts, because they are basically independent and will not lead to discrimination errors. Ranzijn hypothesized that teaching the coordinate concepts in a simultaneous presentation will be more effective in comparison to a successive presentation. For the measurement of the acquired knowledge and skills he used tests for declarative and procedural knowledge. He further hypothesized that subjects in the simultaneous condition would need less time for the development of the concepts then those in the successive condition, because they do not need to retrieve relevant knowledge from memory. Ranzijn carried out two experiments. In the first experiment he used the coordinate concepts, the members of which were presented either simultaneously or successively. In the second experiment he used the successive concepts, the objects of which were presented either simultaneously or successively. For carrying out his first experiment Ranzijn designed and developed a picture book with enlarged defining attributes of the coordinate concepts. For his second experiment he developed a computer-based instruction with graphics. In the first experiment the audio-visuals offered a high degree of realism and enlargement of attributes. Moreover concrete examples of conifer branches with scale leafs were available to check the smell. The results of the first experiment showed that the simultaneous presentation did yield a shorter learning time and better categorization scores on an immediate posttest. For this test the students had to categorize twenty different leaves. The scores on the retention test that was administered four weeks later didn't show the difference. The results of the second experiment again showed that the simultaneous condition did require less learning time. The immediate posttest did not show significant differences in the scores of the students of both conditions. But the retention test showed a significant effect between the scores of the students in the successive and simultaneous condition. However the difference was in the opposite direction, which means that for successive concepts the simultaneous presentation yielded the best result. Ranzijn concludes that the analysis of the content structure of the concepts needs further elaboration. If there is no physical similarity between the objects of categories there may nevertheless be a functional similarity, which is the case with windflowers and insectflowers. The results of Ranzijn's research are thus useful for teaching coordinate concepts and do not produce clear prescriptions for successive concepts. His study also makes clear that instructional-design rules need to be tested in such a way that the results can also be related to the development or construction of knowledge and not only to the effectiveness of the design as such.

The development of conceptual knowledge and the learning of the identification procedure was also studied by Gulmans (1998). He used Tennyson and Cocchiarella's concept teaching model for the acquisition of coordinate concepts (Table 1). The concept shock was chosen as a superordinate category. Three subordinate categories were distinguished: hypovolemic, sceptic and cardiac shock. For these categories different cases were selected. The cases (patients) were shown on video and had to be categorized by students of a nursing college.The superordinate concept was defined as a "state of the human body characterized by the inability of the heart to maintain an adequate perfusion of vital organs". The attributes that are used for categorizing the cases of all the subcategories into one general concept class shock are labeled the relevant attributes. Those that are used for categorizing the cases into one of the subcategories are labeled the critical attributes. Both the relevant and critical attributes can be perceived directly or on a monitor. Because a shock quickly becomes life threatening the nurses should recognize the attributes (symptoms) as soon as possible and take all the steps for which they are responsible.

In one of his experiments, Gulmans compared two instructional conditions. In the first condition the students could study a typical example of a case that was a member of one of the subcategories of shock. The example was presented expositorily on a screen and followed by interrogatory cases. The instruction began with the presentation of information about the patient that was stored on disk and presented orally, e.g. the patient's age, profession, the accident which took place, and so on. The presentation of the example, the instructions and the feedback were all computer-controlled. After the expository typical example, the interrogatory cases of the same type of shock were presented randomly, but also examples of other diseases were included. In the second condition the students could only study the interrogatory cases. Gulmans supposed that the expository example would have a facilitating effect on the acquisition of the concept of shock, because the students could develop a prototype which comprises both the relevant and most frequently occurring irrelevant attributes. In the experiment he also studied the effect of attribute prompting which he realized by marking and contrasting relevant attributes. This technique is especially useful if the relevant attribute is a value or range of values on a dimension (e.g. data that are shown on a monitor: heart frequency, blood pressure, cardiac output). Gulmans hypothesized that attribute prompting would enhance the conceptual knowledge and improve the categorization skill.

For the instructions, simulated patients played by actors who are specialized in imitating victims were used as cases. When the instruction and categorizing of cases was finished three weeks later a transfer test was administered. This test contained 19 cases of real patients which were presented on video. The results of the experiment showed no difference in categorization scores between the two conditions. The students who processed only interrogatory examples performed equally well to the students who studied a best example. For the development of a prototype in memory it is necessary that the students process more expository cases. Then the prototype can probably function as a point of reference. One best example presented expositorily is not sufficient. Gulmans found that attribute prompting yielded a significant effect on processing the information. During instruction, the students in the marked condition processed more examples, needed less time and addressed more questions. However, on the transfer test the students in the non-marked condition performed better than those in the marked condition. This finding was interpreted as a result of increased effort during instruction by those students who had to find the relevant attributes themselves. Thus, marking contributes to the efficiency of instruction, but does not contribute to the effectiveness.

For learning to categorize patients into disease categories the multimedia environment for representing the reality is useful. It is possible to observe all the attributes for categorizing on video. The storage capacity of the video disk was acceptable, and is now improved by the introduction of CD-ROM.

The use of a multimedia environment has advantages and drawbacks. For a paramedical school teacher, for example in a nursing college, it is impossible to visit a general hospital in reality with groups of over twenty students. The use of a multimedia environment brings the hospital to the subsequent teaching and testing. The development of multimedia material can only be done after carefully planning a project. Only projects based on national funding and agreements on the content of the curriculum will lead to an acceptable cost-benefit ratio.

2.4 Research on solving problems of design and the construction of design rules and plans

Solving problems of design results in a sketch or plan. From that sketch an artifact will be made to fulfill a human need. Many categories of problems of design can be made, such as those of the applied sciences (in architecture, in mechanical, electronic and chemical engineering, in computer programming) and those of the arts (composing a piece of music, making a painting, a sculpture). A special category of problems of design comprise the communication problems. All social communicative problems are problems of design that are ill-defined. Solving these problems requires the development of knowledge and a long term training of the communication skills. In the next paragraph these problems will be described.

2.5 Socio-communicative problems

The knowledge that develops as a result of solving socio-communicative problems is labeled as conceptual networks and schemata (e.g., scripts). Examples of such problems are how to give bad news, how to conduct an assessment conversation, how to manage a group, and so on. The problem solving procedure (task) is based on general rules which are relatively unstructured. The rules must be invented by the problem-solver. The problem solving activity involves the use and application of skills for finding solutions, making decisions and thinking inventively. A sequence of steps is constructed to reach the goal. This sequence offers a solid basis for identifying the major processes in solving the categories of problems and provides information on how to support them. For such activities, there are no complete sets of fixed rules which can be put to work. Even if the procedure is correctly applied, there is no guarantee that it will result in the best solution. A solution can only be judged as better or worse. The steps to solve a socio- communicative problem are labelled as the identification of a heuristic.

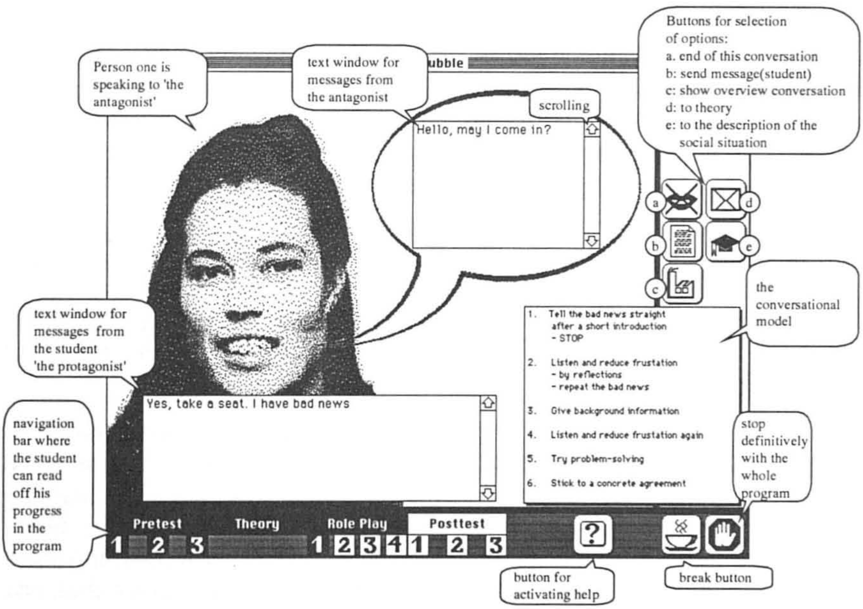
The development of interpersonal skills has rarely been studied. Research on support of technology – computer and multimedia learning environments - to realize effective interpersonal skills development has been characterized as limited and difficult in terms of its conducting, performance evaluation, and the provision of feedback (Campbell, Lison, Borsook, Hoover & Arnold, 1995). Holsbrink-Engels (1998) has studied the effectiveness and efficiency of an instructional-design model for interpersonal skills learning. For studying the effects of instructional-design variables for the development of interpersonal skills, the author developed an instructional-design model for interpersonal skills learning. Ten components of role-play were described, and from these, prescriptions were provided for the design of this instructional method. Role-play was seen as a complex learning environment for novices to develop interpersonal skills, maybe too complex for novices adequately to develop the knowledge and skills. The complexity causes a high cognitive load during the problem-solving process and during the performance in a play. First, the cognitive load is high during socio-communicative problem-solving, because the execution of all steps has to take place immediately in a goal-directed dialogue. Moreover, socio-communicative problem solving is acted out in a play. A play is complex for novices, because the data to be considered for a successful performance is often overwhelming. Further, novices may also fail to develop and practice the intended skills due to a lack knowledge. This only can be constructed from repeated exposures. Only few students can participate in any enactment in role-playing. It is supposed that the complex learning environment confuses novices and thus influences learning negatively.

Another learning environment was proposed. It was suggested that the solving of socio-communicative problems was altered and simplified beyond conventional role-play in order to facilitate learning. Simplification entails the development of expertise, by the solving of simple yet representative kinds of socio-communicative problems. The learning environment is a gradual lead into, not a replacement of, conventional role-playing (Holsbrink-Engels, 1997a).

Two instructional strategies, the use of a conversational model and the provision of opportunities for reflection, were introduced. It was assumed that a computer-based representation of a problem situation can be more useful and possibly more effective for novices, if they use a conversational model which focuses the attention on the necessary steps to solve socio-communicative problems. Further, it was assumed that opportunities for reflection are provided through the education in complexity of the problem situation, and in the freedom from time-constraints in real-life dialogue. The complexity of the problem situation was reduced by stripping away irrelevant and relevant features of a real-life dialogue. The time constraints were diminished by making time available for writing and correcting messages.

Two experiments have been conducted that support the effectiveness of the instructional design model for interpersonal skills learning. Holsbrink-Engels designed and developed an instructional program to train the interpersonal skill "Giving bad news". Four socio-communicative problems had to be solved. The "giving bad news" problems provided different real-world conversations to realize variable performance. The following interpersonal problems were presented. Tell another person that (a) he/she has been turned down for a trip to Australia, (b) his/her report is rejected, (c) he/she has to accept another (lower) position because of reorganization, and (d) he/she has to accept another (lower) position because of personal performance. The problems had to be solved in a computer-based role-play. The interaction between the role-players took place on two physically separated but electronically joined computers. The processes of sending and receiving messages took place through typewritten text in a text- window and bubbles on the computer screen. This dialogue-screen is depicted in Figure 2. The messages were exchanged by Local Talk Network after clicking on a send-button. Two video examples were given before practicing the role-plays.

Figure 2:
The dialogue-screen with a conversational model for the second role-play to practice.



For each role-play the following six stages occurred: (1) an introductory computer-screen with a picture of the building where the conversation should take place; (2) a text-screen with a description of the social situation; (3) a text-screen with a description of the role; (4) a dialogue-screen for role-playing (typing and reading messages); (5) a print-screen to make a printout of the dialogue, and (6) debrief the dialogue by the printout. After finishing the first role-play, the same six stages occurred for the second role-playing and so forth.

The instructional program varied with regard to the use of a conversational model and opportunities for reflection. The instructional-design strategy regarding the use of a conversational model indicated that instruction should offer practice in the solving of interpersonal problems under guidance of a conversational model. The use of a conversational model was realized in two ways. First, before role-playing each student studied a description of the interpersonal skill either with a conversational model or without. The descriptions were further identical. Second, during computer-based role-playing, the conversational model was either in view at all times and was shown on the screen next to the current section the student was working on or was absent.

The instructional-design strategy regarding opportunities for reflection indicates that instruction should offer students enough time to consider their actions by the conscious use of analytical reasoning and planning. Opportunities for reflection were also realized in several ways. Students could revise each message (delete and make corrections) and determine when the next message is exchanged (no or less pressure to respond quickly). It was also possible to read back the dialogue, the descriptions of the social situation, and the description of the role. Students could answer questions on the application of the conversational model (reflection-stimulating questionnaire before 'running the computer-based role-play') and their performances (reflection-stimulating questionnaire after 'running the computer-based role-play').

The first experiment explored the effect of the learning environment on the development of interpersonal skills. In this experiment the students were randomly distributed over two groups. Two types of learning environments were compared, one with and one without computer-based role playing. One major finding was that computer-based role playing fosters interpersonal skills development by: (a) practicing the use of a conversational model, (b) offering opportunities for reflection, (c) performing four protoganist roles, and (d) capturing individual contribution and learning.

In the second experiment, the expected advantages of the two instructional design strategies implemented in the learning environment for interpersonal skills development were examined by comparing four types of the learning environment. Holsbrink-Engels (1997b) expected that the conversational model-present (C^+) groups and the high reflection (R^+) groups would show more effective interpersonal skill development, knowledge acquisition, and a more complete understanding of the skill (better tests results) than the conversational model-absent (C^-) groups and the low reflection(R^-) groups. The learning outcomes were measured using four posttests: (a) performance in a role play, (b) knowledge test, (c) classification test and (d) conversation-sequence test. A registration program was installed in the learning environment. It logged the students' actions, starting and ending times by program sections in a logfile. The logfile of each student was printed and available for data analysis. The results of the experiment revealed a significant interaction between Conversational Model and Reflection Opportunities. The interaction was significant for the Knowledge Test of the learning outcomes. In the C^+ condition, students receiving the R^+ treatment attained more knowledge from the training program than the R^- treatment. In the C^- condition, there were no apparent differences in knowledge acquisition when the R^+ and R^- treatment were compared. In addition to the interaction, a significant main effect for the Conversational Model was found. Students in the C^+ groups performed significantly better in a computer-based role-play than the C^- groups. Also on the Knowledge Test, students in the C^+ groups performed significantly better than students in the C^- groups. Holsbrink-Engels concluded that knowledge acquisition is influenced by a combination of the use of a conversational model and opportunities for reflection. This finding resulted in a suggestion for refinement of the hypotheses about the influence of the opportunities for reflection on the learning outcomes. It was expected that when combined with the use of a conversational model, the R^+ groups would show more effective interpersonal skill development and knowledge acquisition, and would have a more complete understanding of the skill than the R^- groups. This refinement had consequences for the training strategy reflection opportunities: instruction should only offer opportunities for reflection in combination with the use of a conversational model that offers a general heuristic that reflections may refer to.

The use of a conversational model only affects the learning outcomes. C^+ groups performed significantly better than C^- groups on a computer-based role-play and on the Knowledge Test. This finding supported one of the hypotheses of this study. A conversational model accommodates the need of the students for guidance and direction in solving socio-communicative problems. The guidance may direct the attention of students to relevant information which is already in the memory and integrate it with knowledge that already exists. This information can be helpful to the performance of the skill. The result of Holsbrink-Engels' research showed that a computer-based learning environment can be used to assist the realization of an effective gradual approach in learning to solve this category of problems of design and to gradually develop the interpersonal skills involved. Both instructional strategies were found to affect the development of the interpersonal skills of the students. The presence of a conversational model significantly improved the students' skill and their performance on the achievement test. When also given 'opportunities for reflection' the students' performance in a role-play and on the achievement test improved even more. The instructional program comprising a conversational model in combination with opportunities for reflection was therefore considered as useful for introductory problem solving and having the potential to assist in introducing parts of interpersonal skills learning and instruction for novices. Future studies are needed to explore other possible applications of the learning environment. To leave no doubt, there is much work to do for those who would like to use technology to assist in realizing effective interpersonal skills development.

3. Conclusion

The goal of education is that students acquire knowledge, skills and attitudes that are useful and functional both for themselves and for society at large. Knowledge and skills are developed through investigation, problem solving and creativity. It is necessary within education that students have opportunities for exploration, problem solving and design. The situations of instruction in which these activities are possible and in which guidance is available will enhance and support the development of knowledge and the learning of skills. Because these activities are executed on a reality in education the reality needs to be available, either as such or in a mediated form.

In its most simple and abstract form, the reality can be represented symbolically on paper as a model. In this case it should be possible for the students to imagine reality to which the models refer.

A multimedia representation is a form of a mediated reality and such a representation can be functional in education. However such a representation can only be functional if it serves the problem-solving and design activities of the students which are necessary for their knowledge development and their learning of skills. A multimedia representation refers to learning materials which employ different senses simultaneously and if this representation is interactive the students can manipulate the environment, enlarge and explore parts, ask questions and get feedback. The categorization of problem types will be helpful for making a choice as to whether to use a multimedia representation or not.

The designers must decide whether the students should categorize or interpret. If they must categorize based on the change of objects, then they must interpret which process causes the change.

For learning to solve problems of categorization a multimedia reality such as video and sound will be useful if the following conditions apply: (a) the objects, which are dynamic, cannot easily be perceived because they are too small or too far away or the observation of the objects will be too disturbing for it and (b) the objects are living organisms that move and show changes that are important for categorizing. Examples are video's for the categorization of insects and their metamorphosis, of birds and mammals and video's for diagnosing the features of illnesses as is aforementioned. However video and sound in themselves do not stimulate the development of knowledge. Zooming on relevant features, contrasting with irrelevant features and enlarging parts of an object that are relevant for categorizing are the important aspects of a multimedium for learning to categorize.

For learning to solve problems of interpretation, a multimedium such as video and sound will be useful if the objects change in position or in shape. Examples are videos of the movement of planets in the solar system, of the growth rate of plants by time-lapse photography or of the migration and feeding patterns of birds. However, simply portraying the phenomena does not provide the explanation for why objects change.This is rather provided in the formulation of hypotheses and predictions and the testing of them in experiment and observation. Animation and simulation can also provide a perceptual presentation of the process and help to explain it.

For learning to solve problems of design a multimedium such as video and sound is useful for showing and putting into practice the steps of construction of objects and explaining their use. This applies also to revealing a sequence of operations and describing how to repair an object. The use of communication, necessary for the solution of a socio-communicative problem, is one example of this category of problems. Others are the phases and the steps within a phase in constructing a building. Video and sound is often used in showing the function and use of tools, for example in eye operations and dentistry.

The examples of learning to solve socio-communicative problems make clear that the problems that will be constructed for learning differ from the original and real problems. The learning environment offers a model for designing the communication and an opportunity for reflection. The environment is made "less rich" than the actual environment, but this is necessary for the development of the students knowledge and for learning and practicing the skills. The general message is that the designers of instruction must create a learning environment which fosters the development of knowledge and skills and also motivates the students.

The research projects discussed used the multimedia environment for learning, as it was believed to be adequate. The projects were initiated in order to study the development of knowledge through problem solving. The authors assert that a problem-based learning environment will support the students' knowledge development and their skills acquisition. It is made clear that variations in the questions asked and in the presentation of information influence the development of knowledge.

The experiments reveal that the "richness" of the learning environment must be made specifically relevant to the development of knowledge and its employment.

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