10. Developments in the Design of Instruction

From Simple Models to Complex Electronic Learning Environments

Sanne Dijkstra and Henny Leemkuil

University of Twente, The Netherlands

Abstract: This chapter addresses the relationship between the psychology of cognition and learning and the design of instruction in its development during the last half of the former century and the following years in this century. The findings of research on cognition and learning and the applications for the design of instruction become integrated with the developments in information and communication technologies. The chapter shows both the development of the generic ADDIE model and the design of highly specific situated simulation and games.

Keywords: Adaptive learning; ADDIE model; complex learning environments; instructional design; learning support; simulation-based learning.

The Growth of Information and its Influence on Instructional Design

The ever increasing amount of information and problem-solving procedures and the regular changes of both led and still lead to the question how to pass on the content and sequences of operations to members of future generations in such a way that they can use this as knowledge and skills. That question concerns both the education and training in schools and in other organizations such as governments and industry. Of course, this question is not new and answers have been given in the last three centuries. However the increasing amount and complexity of the information and methods content and the need to pass on much of this to as many human beings as possible, made it necessary to continue the study for answers. That study is part of instructional design (ID), an applied science that became established in the second half of the former century. The study and research on ID led to a substantial body of design knowledge and methods and to many useful instructional programs. The purpose of this chapter is to provide a concise overview of the developments of ID and to show how these developments have led to rather diverse results: to the general ADDIE model on the one hand to situated instructional games on the other. This will be explained and illustrated.

The field of Instructional design (ID). The organizations and situations of education and training comprise the field of ID. The goals of these organizations are to pass on the information and problem-solving methods to members of future generations or to the members of the organizations. ID will at least support these goals. The design of instruction is the design of the communication between an expert (teacher) and a novice (student) in such a way that the student will acquire the knowledge, skills and attitudes that are the goal of the curriculum. Instruction is any intended activity to make that acquisition possible or easier to accomplish. The acquisition of knowledge and skills is a psychological process. Instruction should facilitate that process in the best possible way. The students have to cognize the content of the instructional communication and to practice the procedures in order to become skilled performers. The result of the design of instruction can be delivered as an instructional program in printed or electronic format in order to either be used by individual students for self-study or to be used with all kinds of help of an expert.

Foundations of Instructional Design

There have been many developments in the design of instruction. The authors cannot do justice to all developments here. In Europe the concept of didactics is used. In a recent publication Seel and Dijkstra (2004a) provided an overview of studies into this concept and its relationship with the concept of ID. Instructional design started and became established as an applied science in the last half of the former century. Seel and Dijkstra mention three sources for the development of a theoretical basis for the design of instruction, which will be shortly outlined in the next paragraphs. These are (a) the psychology of cognition and learning, (b) the engineering or systems approach to education, and, (c) the information and communication technology. A fourth source is the epistemology of knowledge acquisition.

The Psychology of Cognition and Learning and Instructional Technology

There will be no doubt that learning is a psychological process, though actually the whole human organism is involved during learning (Dijkstra, 2004a). Before the 1950s the foundation of instruction in the psychology of learning was often made, but a direct relationship between the science of learning and an instructional technology was missing. Skinner (1954, 1958) was the first to state the rules for solving an instructional-design problem and to construct a device — the teaching machine — to apply the rules that make learning possible. Though the idea of a science of learning and a technology for teaching and learning was admired, the interpretation of all learning as instrumental conditioning was soon abandoned. Moreover the rules for programming instruction and the use of teaching machines did rarely lead to the promised results. As Seel and Dijkstra concluded: 'The application of the rules led to a splitting up of the subject matter into a huge number of instructional frames that were even able to prevent the integration of the concepts and methods involved. The teaching machines were not able to adapt the instruction to the students' learning flexibly' (p. 5). A new theory, a new technology and better devices were needed. These will be discussed in the next section. Nevertheless, Skinner realized the elsewhere productive relationship between science and technology for the psychology of learning and marked the beginning of instructional design as an applied science. Moreover he developed technical equipment for the application of the design rules.

The Systems Approach to Education

The whole process of teaching and learning can be described in a sequence of components. For this process Glaser (1964) used the technical term instructional system that consisted of five components: (a) the instructional goals or system objectives, (b) the students' entering behavior of system input, (c) the instructional procedures or system operations, (d) the performance assessment or output monitor, and, (e) the research and development logistics. The objectives were formulated in observable behavior; the instructional procedures and the assessment of results were founded in the theory of learning and educational measurement. The systems approach became influential for ID. An instructional system provides the instructional designer a soft technology to hold on (see next paragraph).

Technology and Technical Equipment

A technology is the whole of the science (theory and research methods) that is valid for a domain and of the rules for solving a design problem in that domain in order to realize a public or individual goal. For example, chemical technology comprises the theory and research methods that are valid for the molecules of substances (their structure and their change) and the rules to construct devices and installations for producing substances that will be used for a public or individual goal, such as refineries for producing gas for transport and heating (Dijkstra, 2004a, p. 17). If the rules are well-defined the authors suggest the label hard technology. If they are ill-defined, the label soft technology is preferred. Soon after it became available, the technical equipment that was based on laws of physics was used in education and training. As Seel and Dijkstra stated, in the 1950s and 1960s the teaching machine, television and the language laboratory were used in schools. Nearly all this equipment became replaced by microcomputers. By the end of the 1970s the information and communication technology entered the field education and training definitely. Though minicomputers were already used for instructional purposes in the early 1960s, the invention of the microcomputer by the end of the 1970s had a tremendous influence on education, both in the use of the hardware as well as in software. The increasing qualities of the computer equipment were: (a) smaller equipment, but more information storage and (b) faster in processing information. The digitalization of all information, including large amounts of visual information and the developments of communication technology led to a pervasion of all sectors of the industrial and everyday world (Seel and Dijkstra (2004b). For instructional communication the computer equipment did replace nearly all other devices that were used previously, such as the slide, the overhead and the film projector. For providing information a computer and a beamer produce at least the same quality of text and pictures. Streaming video, which is a sequence of movie parts that is sent in compressed form over the Internet, makes it possible for the students to see a movie for instructional purposes, without the need to first download the whole movie. Thus the student does not waste time. Today, for an appropriate computer-supported instructional communication the student can interact (a) with the subject matter content, both with the objects that are mediated and with the text, and can get the best possible feedback immediately at any distance from school, (b) with the teacher at any distance, (c) with peer students at any distance, and (d) with the Internet as a library. Besides the hardware qualities the software is still becoming more "intelligent" in initializing and supporting instruction and learning. Special applications, such as animations, simulations and games may help the students' understanding of the subject matter. All the features of the computer, both hardware and software, became integrated in education and training.

The Epistemology and Knowledge Acquisition

If the goal of education and training is described as the acquisition of knowledge and skills the instructional designer needs to have at least some idea of what knowledge is and what this means for the acquisition of knowledge. Situated cognition (Brown, Collins and Duguid, 1989) and constructivism (Glasersfeld von, 1996; Jonassen, 1992; Piaget, 1937) will get some attention in one of the next sections.

The Developments in the Psychology of Cognition and Learning

About 1960 and afterwards the model of instrumental conditioning as the only model for the description and interpretation of human learning was rejected. The change of the theories of learning became known as the cognitive shift that led to several new concepts and interpretations of the human actions. The authors of this chapter first make a general assumption. They assume the existence of cognitive entities, such as a semantic network and cognitive processes, such as the mental operations in problem solving. The conceptions of the psychology of cognition that influenced the development of ID as an applied science encompassed the existence of categories of human learning, of cognitive processes and of memory structures. It has led to many new conceptions about cognition and to several applications. For this chapter the categories (conditions) of learning and the conceptions of semantic network, cognitive structure and mental model will be discussed concisely, more or less in chronological order.

Bruner, Goodnow, and Austin (1956) showed the existence of cognitive processes for the formation of concepts. The participants in their studies constructed identification algorithms in order to categorize objects. Based on tentative categorizations of artificial objects, such as rectangles and crosses, they constructed provisional concepts. As soon as their categorizations proved to be always correct either conjunctive or disjunctive concepts were formed. Thus concept learning as a category of learning could be described and the process of acquisition could be shown in detail. A few years later Melton (1964) published a book on categories of human learning, soon followed by a comparable book on the conditions of learning (Gagné, 1965). The latter seminal publication is often considered as a basis for the design of instruction. Gagné distinguished different types of learning that could be realized if special conditions for that type were met. Among these types he mentioned stimulus-response learning, chaining, verbal association, multiple-discrimination learning, concept learning, principle learning and problem-solving. Of these types of learning he provided examples all taken from the curricula of elementary and secondary education. All types of learning had an outcome that is described in observable behavior. The types of learning were ordered from simple to complex. Gagné showed some learning structures. The ultimate objective of a learning structure was the acquisition of complex behavior. A learning structure is a sequence of different types of learning that are organized in a hierarchy. One example given showed the structure for learning to read larger units of text in English language (p. 201). The content of this structure was ordered from simple to complex types of learning. The instructions to support the learning of the content of these types should follow the order given. For structuring more complex content, consisting of concepts and principles, the label learning hierarchy was introduced. For determining the most plausible structure of a learning hierarchy the final learning outcome must be broken down into outcomes on a prerequisite level that is one step lower in the hierarchy, and so on, until the level of concepts and principles, the content of which the students already know is reached (p. 188). In order to be able to acquire the concepts and principles at a certain level, those of the lower level have to be mastered. The results of research by Gagné and his co-workers (e.g. Gagné et al., 1962) did support the description of the conditions of learning and the concept of hierarchies of learning.

In the following decades the idea of different categories or conditions of learning was influential. For example Merrill (1983) and Reigeluth (1983) used the same categories. The research on concept learning and problem solving did strongly support the assumption of the existence of these categories of learning. The learning structure and learning hierarchy, which were constructed after the final learning outcome was analysed into the lower levels of concepts and principles of a domain, could be compared with the idea of cognitive network or cognitive structure. These are assumed cognitive patterns of organizations of knowledge components. Such patterns are represented in graphs. Strong support for the idea of a hierarchical network was provided by Collins and Quillian (1969). The Collins and Quillian semantic network model, which was represented in a graph, organized concepts in a hierarchy of subcategories in such a way that the most general concept was represented at the top of the hierarchy and the most specific concept was represented at the bottom. All concepts (categories) at a lower level were subcategories of those at a higher level. Collins and Quillian (1969) supposed that the properties of the instances of a category are stored only once at the highest possible level in the hierarchy. For this principle they found evidence in the reaction times on determining the correctness of statements. For example, the duration of the reaction times to verify the correctness of the following three statements about properties (a) a canary can sing, (b) a canary can fly, and, (c) a canary has skin, showed a significant increase. Property (b) is stored at the represented category birds and (c) at the category animal. Starting at the category canary to check for the relevant property, the traversing of the hierarchical network takes time. A semantic cognitive network can take on other structures. For the representation of the causal structure of a domain Collins and Stevens (1983) used an and/or graph. Such representations are useful for the design of a detailed instructional communication. They showed how different rules of inquiry teaching can be used to enable students to extend their fragmentary knowledge of such a structure into the complete knowledge network. Each inquiry rule provides the students with a problem that can be solved by reasoning with the knowledge they have. If the students don't know or seriously hesitate the teacher can provide the information.

Though the assumption of a pattern of knowledge components as a cognitive structure is useful for the design of instruction, it does not interpret the dynamics of knowledge use to reach a goal. For that the concept of mental model will be discussed.

Mental models and goals. Human behavior is motivated, either for doing a job or for other goals. If a motive is active human beings will execute the steps to reach the desired goal. They will work from the actual situation to the desired goal state in a goal-directed interaction with the environment. For appropriate actions they need a model of the complex reality in which they work or function. Only understanding the processes and procedures to change the given situation make the fulfillment of the motive possible. Therefore understanding the processes of change and the procedures to design, develop and use artifacts are such important goals of education. For the goal-directed interaction with the environment it is supposed that human beings construct mental models. As Norman (1983) described it: "In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction." (p. 7). Mental models are representations of real or imagery situations. As Seel (2004) wrote: "..models are always constructed in accordance with specific intentions of the model building person. Models are always representations of something; they represent natural or artificial objects, so-called originals, which can be again models of something." (p. 54). Mental models are the result of reflection about objects and how these change. Everyday human beings make use of mental models or are constructing and changing models. For example the development of a mental model of the road plan in a new city area. Sometimes international agreements are made about the representations of objects. For example the particle model in chemistry to designate atoms and molecules and their change is represented all over the world in the same way, both in icons and in symbols (see the chapter of Jonassen and Young in this volume). Human beings are creative in constructing mental models that are used as metaphors. The reader is referred to the container model, an example discussed by Lakoff (1987).

How can the concept of mental model be useful for the design of instruction? The authors suggest that the instructional designers make problems in such a way that the students need to observe and manipulate concrete objects or representations of these. The information given must lead the students to observe defining and characteristic features of the objects. The goal of the manipulation of the objects is that the students can find regularities in the behavior of those objects. These objects must be available or represented in such a way that the students can make predictions about what will happen over time. Information and communication technology can be of substantial help, especially if the objects are complex and situated. An elaborate example of a company as an object will be given later in this chapter.

The new conceptions of the psychology of cognition and learning formed a rich foundation for instructional design. Nevertheless it did not lead to full agreement about the rules to apply among instructional designers as will be shown in the following sections.

General Models of Instructional Design

The label design is used by Gagné (1965) when he outlines the predesign of the conditions of learning and outlines the principles of design for those conditions. A few years later the label instructional design is used (Gagné & Briggs, 1974). In the following decade more and different instructional-design models were published. Nearly all models clearly show the phases of solving a design problem, comparable to solving practical problems in the engineering sciences (Dijkstra, 2000).

In his first attempts to solve instructional-design problems, Gagné integrated the at that time relevant conceptions of the psychology of learning, both from behaviorist psychology and from the first studies of cognition into the design of instruction. This led to emphasis on the description of learning outcomes as capabilities and to the categorization of the learning content as mentioned afore. In the following decades the ideas became worked out (Dick & Carey, 1978; Gagné & Briggs, 1979) into instructional-design models. Gagné and Briggs (1979) extended the categories of educational goals to intellectual skills, cognitive strategies, verbal information, motor skills and attitudes. The original categories of concepts and principles became subsets of intellectual skills: concrete and defined concepts, rules, higher order rules and problem solving. The phases or series of steps of the instructional-design models start with a description educational goals (see Gagné & Briggs, 1979) in terms of the students' behavior or capabilities. The more general labels knowledge and skills were not used in those years. These conceptions were directly useful as design rules, such as the analysis of the content of subject matter and to the analysis of educational goals into hierarchies of concepts and principles. These rules were helpful for the overall instructional design. For separate conditions of learning the design rules could be worked out into nine events of instruction (see Gagné & Briggs, 1979, for a detailed description). Other scholars emphasized different aspects in their instructional-design models. In an anthology, edited by Reigeluth (1983), different instructional-design theories and models were presented. These models show the phases or clusters of steps how to solve instructional-design problems. It was supposed that the models did apply for all domains and fields. However those who invented the models nearly always used isolated examples of domain knowledge and problem-solving procedures from mathematics and physics, in any case well-defined procedures. Nearly all models structure the content of the subject matter into the categories that Gagné had provided. The models specify the concepts that can be used to describe the content of the curriculum and the main variables that should be considered for the design of the instructional messages. They further provided rules to describe the educational goals and often give examples of achievement test items that can be administered to the students in order to evaluate their performance. The instructionaldesign models show much overlap. By the end of the 90's of the former century, a generic approach, already recognizable in the Principles of Instructional Design by Gagné and Briggs (1979), was referred to as the ADDIE model.

The ADDIE Model of Instructional Design

The characters mean analysis, design, development, implementation and evaluation. A clear origin of the acronym is not found (Molenda, 2003). The model became a pragmatic tool for instructional-design projects. The results of each phase are evaluated and used to alter or reinforce the steps in former phases (feedback function).

Analysis

Depending on the purpose of the project, the analysis phase becomes worked out into needs analysis, subject matter content analysis and job analysis. This results in a description of the learning objectives for a certain group of students. The description will profit from an assessment of the students' knowledge and skills that are conditional to understand the course content. The analysis phase results in the program of requirements described as knowledge and skills to be acquired and in the design of a prototype of an achievement test to be administered by the end of the course, together with the description of a criterion score that marks the level of knowledge and skills that the students should reach.

Design

In the design phase the instructional-designer makes a general plan for the arrangement of the content of the instruction. It contains the categories of problems to be solved by the students, the procedures how to solve these, and the concepts, hypotheses and theories that the students should understand, remember and use.

Development

The development phase results in the course materials that are ready for use. During the development the evaluation of the first release leads to corrections and to a second release of the course materials. This process can be repeated until a satisfactory product is constructed. If the materials will be presented online, corrections are based on the students' errors. Regular formative evaluation with a group of students will support the development of a useful product. The developers will require an expert evaluation as well.

Implementation

The implementation phase may comprise different jobs, such as training the trainers, scheduling the courses, preparing a time table, scheduling evaluation sessions and so on.

Evaluation

Finally in the evaluation phase different assessments can be made, such as: (a) the students' affective reception of the course, and (b) a measurement of their achievement. Do the knowledge and skills that are acquired meet the learning objectives and the criterion that they were told? Do they apply what is learned in their jobs? The results of the evaluation serve the purpose of feedback, both for the instructional designers who can improve the design and the course materials. Moreover they provide feedback for the boards of executives of companies and of schools whether their goals became realized.

At first sight the generic model seems useful for those who are responsible for education and training in school systems and in business and industry, certainly if they don't have much knowledge of the psychology of cognition and learning. Most probably the thorough analysis of the subject matter and the direct approach of instruction to which many students are used, underlines their success. In many training institutes the model was accepted and became leading for the design of instruction. Today many universities show the model on their websites, the purpose of which is to help their professors with the design of their instructions. And many training institutes advertise the model to their clients to convince them of their expertise in course design. In spite of the growing use of the model as a generic model for instructional design criticism remains, both on practical and theoretical grounds.

A first practical criticism refers to the often too detailed prescriptions for the five phases, as a result of which the designers don't see the wood for the trees. It makes the use of the model inefficient and ineffective (Gordon & Zemke, 2000). Secondly, the model leads to a linear way of working, which can easily result in a rigid course program that is unable to resemble the flexible communication between a teacher and a student. The model should use the advantages of digital technologies, such as rapid prototyping (Tripp & Bichelmeyer, 1991) and should leave room for individualization.

The models were seriously criticized on epistemological grounds (e.g. Jonassen, 1992). Too often the students were provided information about objects, instead of providing opportunities for the construction of knowledge from the real objects or from those that are mediated (Seel & Winn, 1997). A separate task of media selection, which became part of the set of design rules, for example selection of classroom instruction, written materials or e-learning is at best pragmatic.

It ignores the essential meaning of the concept medium as a way to represent the reality. The authors' students of instructional design had serious difficulties to analyze the information of a textbook into concrete and defined concepts, rules (principles) and higher-order rules. This was one of the reason's to abandon the use of those categories and start from problem solving as the students' activity to construct knowledge from the reality. The reality is specified by the concept of object of a domain. An object can be categorized, its change can be interpreted and it can be designed as an artifact. Information about the objects can be provided to the students and questions can be asked. These questions are the problems of categorization, of interpretation and of design. The label object can mean any entity that is perceived or imagined. Instructions are about objects and what to do with them (Dijkstra, 2004b). These include (a) real objects such as plants, birds, houses, cars, the earth; (b) inferred objects, such as atoms, the psyche, a group; and (c) systems, such as the solar system, a taxonomy, a machine, a company, a political system. For the design of instruction the object can be real or needs to be mediated for and during instruction (Dijkstra, 1997, 2000, 2004b). The mediated object should help the student to develop a mental model of it.

These criticisms about the ADDIE model make sense. The designers are suggested to start with a general description of the final goal and then work with broad outlines of the phases of the model. The designer should prevent to get swamped into a too detailed set of steps at the start of the procedure. Further a pretest and regular formative evaluations during the development phase can make clear what the students already know and what their learning needs are. Though the ADDIE model is a useful model for instructional design the user should be aware that it only is a general heuristic.

Mental Models and the Design of Instruction

Human beings have an ability of modeling the world. They anticipate a new situation that they expect or predict to happen from their actions or from the events they observe. The expectations are based on experiential knowledge and the theories they know about the change of objects. (Seel, Ifenthaler, & Pirnay-Dummer, in press). It is supposed that the development of mental models is a long term process. The models can develop to a high level of abstraction, for example a model of a refinery. The assumptions on the development of mental models lead to a design of a learning environment and a choice of real or represented objects that are needed for manipulation by the students, both for categorizing the object and for eliciting change. Moreover the objects are needed for the reflection on their behavior. During instruction for the acquisition of knowledge students try to develop a mental model of the objects that are used to clarify and explain the knowledge. And they manipulate the objects for studying their features, their change and for practicing their skills. The mental model is used to plan future actions and to predict the results of an action. During the whole period of elementary and secondary education the models of the reality and of domains of that reality change and are becoming increasingly complex. The models of real and mediated objects play a crucial role in solving both well- and ill-defined problems. For example, the value of assets at the stock market can be calculated precisely, based on the values of the variables given, but the prediction of the amount of change of value over a certain time lapse is very difficult if not impossible.

For functioning in a complex environment the use of complex ill-defined procedures is needed, such as logistics for building construction, rules for leading a department, a company, an army, and so on. In such situations different variables and their interactions do influence the outcome of human actions. How can instruction help the students to develop a mental model of the organization, its structure and the effects of possible actions on the output of the system or organization? Cognitive flexibility theory and mental model theory were used and did support to design the instructions for learning complex ill-defined procedures that can be applied in complex environments (e.g. industries).

Virtual learning environments. How can students learn to construct a mental model of a complex reality such as an engine or an industrial enterprise? This is possible in a long time apprenticeship that can be supported by a simulation of the object (e.g. engine, organization, and so on). Achtenhagen (2004) provides an example of an industrial enterprise. It is supposed that the mental models change as knowledge and skills increase and if making predictions with a model fail.

The instructional design for the construction of mental models of complex artifacts of technology and of complex structures in an educational setting meets some difficulty. An interaction with the environment is needed, thus on the job training prevails. However, unskilled personnel can easily make mistakes, which involve a risk for damage and personal safety. Moreover the complexity of a system may evoke a model that is only partly useful and will easily lead to errors. To prevent these, the use of a complex electronic learning environment may be designed and turn out to be helpful.

If a complex reality such as an industrial enterprise is simulated for the purpose of learning, its structure should be depicted in such a way that the effect of an intervention and the consecutive process can be illustrated. As Achtenhagen makes clear, the design of a virtual enterprise for the purpose of learning consists of two steps (a) modeling the reality, and, (b) modeling models of reality from a didactic perspective. For the second step the designer should balance the information given and the questions asked. The instructional communication starts with the presentation of information, both the description of the features of the system or organization and their structure, the concepts and the illustration of the method how to manipulate the objects. It is the explanatory part of the instruction. This part is needed to coach the manipulation of real objects and the study of the meaning of the depictions. Worked examples of problems will be presented and discussed. These will be followed by real problems, which the students should solve by using the knowledge and the methods to reach the goals. In the next section a complex virtual environment is outlined. These environments can also be used by employees who start working at a company and for web-based education and training

(Perez, Gray, & Reynolds, 2006). The use of simulations and games for learning to operate in a complex company is discussed and shown in the next sections.

Simulations and Games for Learning to Model Complex Realities

The Construction of Knowledge

Simulations and games can be powerful tools to help develop concepts, principles and schemata of complex systems. They can have a role in education and training in putting learning into a context. Furthermore, they are environments in which students are invited to actively solve problems and thus construct their knowledge. Games and simulations provide students with a framework of rules and roles through which they can learn interactively through a live experience. They can tackle situations they might not be prepared to risk in reality and they can experiment with new ideas and strategies. They involve individual and group interpretations of given information, the capacity to suspend disbelief and a willingness to play with the components of a situation in making new patterns and generating new problems (Jacques, 1995).

Information and Guidance

Van Merriënboer (1997) stated that constructivistic and instructivistic approaches of instruction and learning need not be seen as distinct alternatives, but merely as two aspects of instruction that can, and often should, complement each other. In order to make the training process more efficient, it is sometimes necessary to provide the learners with pre-specified, general knowledge that may be helpful and offer guidance to solve the problems in a particular domain. Recently, Kirschner, Sweller and Clark (2006) also pointed to the fact that some form of guidance is needed in rich problem based experiential learning environments to prevent that learners miss essential information (see also Mayer, 2004), experience a cognitive overload, and are not able to construct adequate mental representations. De Jong and van Joolingen (1998) have argued that in simulation based inquiry environments learners often experience problems. They stated that cognitive scaffolds should be integrated into simulation based environments to support learners. Cognitive scaffolds may structure a task, take over parts of a task, or give hints and supporting information for the task. If this is true for simulations than this is also true for games, since games and simulations have a lot of elements in common.

Games and Simulations

Games are competitive, situated, interactive (learning-) environments based upon a set of rules and/or an underlying model, in which, under certain constraints and uncertain circumstances a challenging goal has to be reached. In games players (sometimes in cooperation with others) are actively solving challenging situated problems. Simulations are environments that are also based on a model of a (natural or artificial) system or process. In a simulation learners can change certain input variables and can observe what happens to the output variables. The main distinctions between games and simulations are that games contain elements of competition, chance, surprise, and fantasy that are not found in simulations. Furthermore, the goals are different. In simulations the goal is to discover the underlying principles of the simulation model, while in a game a person tries to win the game, get the highest score or beat the system or other players. In a simulation the learners have more freedom to act and experiment and in most cases they do not have to cope with limited resources. Finally, in a simulation it is relatively easy to recover from wrong choices. In games participants have to think about the trade-off between costs and profits of actions and most often it is not possible to "undo" the actions. One has to face the consequences of one's actions, while in a simulation it is easy to restart and experiment in the same situation.

Support for Learning

One of the elements that could be added to the didactical context to support players is a debriefing activity. This is advocated by several authors (Garris, Ahlers, & Driskell, 2002; Klawe & Philips, 1995; Peters & Vissers, 2004). Debriefing supports reflective thought. Although there is consensus on the role of debriefing, in the literature about learning with games there are only a few studies that present data about the role of other supports. Stark, Graf, Renkl, Gruber, and Mandl (1995) focused on a problem solving scheme, Leutner (1993) on just-in-time information and advice, and Halttunen and Sormunen (2000) on feedback.

Leutner's study showed that different types of support could lead to different results. He found that advice (provided by means of warnings if decisions are likely to lead to problems) increased verbal domain knowledge, but decreased game performance. Furthermore, his data indicated that system-initiated adaptive advice had short-term effects (measured directly after game play), while learner requested non-adaptive background information had long-term effects (measured by a test that was administered a week after game play). This raises the question which combination of scaffolds is most powerful? To get a first clue about this, three studies were performed in which a game was used that contained a set of supports. The game and the scaffolds that are implemented are described below.

KM Quest: A Simulation Game about Knowledge Management

KM Quest is an Internet based simulation game about knowledge management. It was used to study the effectiveness of a combination of scaffolds (Leemkuil et al., 2003). Several universities and institutions for higher education in the Netherlands have used and still use the KM Quest learning environment in courses on knowledge management. The goal of the game is to learn basic knowledge management concepts and actions and the steps of a systematic approach to solve knowledge management problems. Furthermore, the goal is to learn to assess the KM situation of an organization and to advise/implement appropriate interventions.

In the simulation game KM Quest the player takes the role of a knowledge manager in a fictitious large product leadership organization named Coltec. The task of the player is to improve the efficacy of the company's knowledge household. More specifically, the goal of the game is to optimize the level of a set of general organizational effectiveness variables (or indicators): market share, profit, and the customer satisfaction index, by influencing the effectiveness and efficiency of knowledge management processes (knowledge gaining, development, retention, transfer and utilization). These processes can be influenced by choosing and implementing interventions from a pool of 57 possible interventions. The game is driven by an underlying simulation model that combines the organizational and knowledge management variables (see Shostak & de Hoog, 2004). Most of the indicators in the simulation model are characterized by a decay factor. This means that the value of the indicators decreases over time when no interventions are implemented.

In the game, players can use several resources while performing their task. They can inspect the status of business process indicators and knowledge process indicators that are incorporated in the simulation model, and they can inspect additional information about interventions, indicators etc. The implementation of interventions involves costs, as well as several other activities that the players can perform. Players receive a limited budget that they can use to implement interventions and buy information.

A three year period is simulated (divided into 12 quarters). Changes in the status of the business indicators are only computed at the end of each quarter. At the beginning of each quarter an (unexpected) event is introduced that could affect the knowledge household of the company. Players have to decide if and how they want to react on these events. Events are generated from a pool of 50 events. Different types of events can be distinguished based on two dimensions: the locus of the event (internal or external), and the effect of the event (direct, delayed, or no effect). Effects either can be positive or negative. For instance the following event will have a negative influence on market share: "Gluco has bought the company STIK, which has a strong position in industrial glues. It intends to expand the R&D department in STIK in order to strengthen its position in the Do-It-Yourself (DIY) household glues".

Fig. 1. Virtual office interface.

There is no time limit to playing the simulation game. Players set their own pace. When players think they know enough to solve the problem, they indicate that they want to implement the proposed interventions. After the implementation the simulation game proceeds to the end of the quarter and the business simulation will calculate new values for each of the business indicators. The game ends after players have indicated that they have implemented the last intervention(s) in the fourth quarter of the third year in the life span of the company.

Players can interact with the environment by using tools and resources that are presented in an Internet environment, based on a "virtual office metaphor" (see figure 1). Clicking on a specific element in the "office" will open a window with additional resources or tools. To support the learners in performing their task and to support learning while playing the game several features have been implemented in the environment: a knowledge management model with shared worksheets, a help functionality, just-in-time background information, feedback, advice, visualization tools, and monitoring tools. The knowledge management model and process worksheets describe a systematic approach to solving KM problems and provide support by structuring the task and dividing it in phases and steps. Just-in-time background information supports players by giving access to domain and task relevant knowledge at any time needed. It is available by means of what and how files attached to the worksheets and by means of books (like the intervention and indicator handbook) that are placed at the bookshelves of the virtual office, the organigram (a link to static information about the company), and a help functionality in the task bar (green circle with question mark).

Feedback supports players in evaluating their actions. There are two types of feedback: dynamic feedback consisting of data generated by the simulation model, and pre-canned conceptual knowledge about knowledge management that is based on the experiences from KM experts and is coupled to certain events. The latter contains information (reference data) about the type of event, the knowledge domains and the knowledge processes that it is related to. Furthermore, it contains a list of interventions that are considered to be relevant to react upon this specific event. Players can compare their own interpretation of the event with the description given and can compare their actions with the suggested interventions.

Furthermore, the environment contains advice that supports players by giving warnings and hints. The advice is only available when certain values in the business model are below a fixed threshold value. The advisor icon in the status bar (a triangle with a! in it, see figure 1) normally is passive but starts blinking when advice is available. When the player clicks on this icon pre-canned text will be displayed that warns that there is a problem and that gives hints about what one can do about this problem by means of a reference list to suitable classes of interventions.

To help the players with interpreting the values of the large set of indicators and with seeing trends in the data, several types of visualizations are implemented like line or bar charts (available by means of the icons on the whiteboard). The last type of support consists of monitoring tools consisting of 12 quarterly reports that are available on the top two bookshelves (see figure 1). These reports give information about the players' actions and about data generated by the system in the quarters that are completed. This supports reflection by giving players the opportunity to go back in time without having the opportunity to reverse activities and/ or actions that they have chosen.

Results with the KM Quest Simulation Game

The results of the experiments with the simulation game showed that the learning environment was effective (Leemkuil, 2006). The differences between post-test and pre-test scores were significant. The data show no relationship between game performance and post-test scores or knowledge increase. On the one hand this means that the learner does not have to be successful in the game to learn, which indicates that it is important to make a distinction between the goal of the game and the learning goal. In a game these two need not be the same. On the other hand this also means that in some cases students can be successful in the game while a learning test does not reveal an increase in knowledge.

Support Tools

In the game that was used in our studies several support tools were implemented. The assumption was that in learning environments like games all kinds of barriers to game play and learning could occur that would lead to ineffective learning, and to prevent this, cognitive scaffolds should be integrated that may structure a task, take over parts of a task, or give hints or supporting information. The data indicate that the tools with domain related background information, feedback with reference data and advice were frequently used by the players. The use of advice has a significant relationship with game performance as indicated by the level of a set of indicators in the business simulation model, but does not have any relationship with knowledge increase. There are some indications that the use of background information and process feedback have a positive effect on learn ing and transfer. This is in line with research with simulations (de Jong & van Joolingen, 1998) which also emphasizes the importance of direct access to domain information. This finding also emphasizes that it is important to make a distinction between scaffolds that support game play and scaffolds that support learning from the game.

Our studies focused on scaffolds that could be incorporated in the game itself. Probably the acquisition of new knowledge will profit from support that is not in the game itself but in the setting in which the game is used like a debriefing session after game play. In the past years several authors, like Dawes and Dumbleton (2001), Gee (2003), Kirriemuir and McFarlane (2004) and Jansz and Martens (2005), have stressed the importance of the social aspect of game play. When people think about children playing computer games the prevailing image is that of a boy sitting alone behind a computer screen. This image is too short-sighted because in many (internet) games players play together with others and furthermore after game play much discussion is going on with others about the game experiences and (during or after game play) knowledge and strategies are exchanged between players. Kirriemuir and McFarlane (2004, p. 27) stated that there are indications that interaction in (online) communities could contribute significantly to learning related to games play.

Thus, supports that focus on the social aspect of learning like collaboration in teams, classroom discussions during the period the game is played and a debriefing session after the game has ended could be powerful. These supports can foster a reflective strategy during the game and reflection after the game is played because players have to make their ideas explicit to be able to discuss with others and to exchange experiences. Furthermore, such supports make it possible to compare strategies and their results, to discuss the role of good or bad luck and could enhance the transfer of knowledge gained while playing the game to “real” life.

Concluding Remarks

During the second half of the former century instructional design became established as an applied science. The design knowledge and rules have firm grounds in the psychology of motivation, cognition and learning, in systems theory, in information and communication technologies and in epistemology. However the design knowledge and rules did not lead to uniformity of instructional designs. Of course, the results of a design in whatever field differ, because of the designer’s creativity. Teaching has its own rules, but how these are applied is an art. For the design of instructions the design knowledge and rules have led to both general models and to highly specific situated electronic simulations and games. This chapter illustrates how this could happen. The features of the general models showed much overlap. They finally became combined in one generic model, labeled the ADDIE model. It is a general heuristic for the design of instruction. The model is used frequently and strongly supports the designers. They can fall back on it, which means that all the necessary steps to reach the goal will be taken. The use of the model is no guarantee that the instruction will be successful. The main shortcoming of the model is its lack of prescriptions how to design the mediated content of the instructional communication. Both the information and the representation of the object (s) involved and what the students must do with these. The acquisition of domain knowledge and skills to operate on and with objects requires that the students have to manipulate the objects for answering questions about their features and their change. Only then a mental model of a part of the reality can develop, both from the domain involved and from the field in which the student works or will work.

As is shown in this chapter the information and communication technology made it possible to simulate complex industrial environments. This type of instructional environments allows the participants to study the effects of their manipulations on several organizational variables. The simulation provides the participants a rich environment to develop a mental model of the organization and knowledge about the results of an intervention, without risk for damage. For the development of a mental model of the organization the simulation has two special advantages. It can be used in and outside the real organization and with or without peers. The first advantage means that students who are still at school for vocational training can develop a mental model and those who are still working can study what will be the effect of an intervention. The results are promising.

Though the developments shown did solve difficult instructional problems a few unsolved problems on cognition and learning still result in criticism of the instructional designs. The first problem concerns the relationship between the information given (the explanation) to the students and the amount of time to be spend to the students' own problem-solving activity. Mostly both are necessary. The second activity is crucial for firmly embedding the knowledge into the students' cognitive structures. The second problem concerns the development of and embedding of abstract concepts, principles and procedures from different contexts in the learner's cognitive structure. Learning from one situation does insufficiently foster the development of abstraction. Those concepts that are firmly rooted in cognitive structure are supposed to be well applicable. Both problems need further study.

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