2

Intelligent Tutoring Systems: Preliminary Thoughts

This chapter introduces the educational background of the INTUITEL concept. It argues from general considerations to actual problems. First, basic structural elements of organized teaching and learning processes and an interpretation of these elements for teaching and learning are laid out. Second, implications of using computer technology as a medium in organized teaching and learning processes are discussed. Third, the history of adaptive assistant systems for educational processes is presented. Fourth, conclusions from these preliminary thoughts are drawn.

2.1 Organized Teaching and Learning Processes

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Dead people don't learn. While this might read a bit too existentialistic for the beginning of a chapter about adaptive assistant systems for educational processes, it is helpful to open up two perspectives: First, computers do not live. Thus, they cannot learn. Second, learning is closely connected to being alive. While we will discuss the first point later on, the second one allows us to make some basic distinctions here.

In some theories, all processes are understood as an exchange of information, no matter if the processes take place in the context of a living being or in the context of some dead matter. If it's all just about an exchange of information, there is no clear criterion to distinguish between living beings and dead matter. The exchange of information in these theories just means that they are transferred from one process to another.

But the transfer of information can be understood in two ways: First, the transfer can be understood as copying. In that case, the receiver just adds the received information to the information stored in the receiver. Second, transferring can be understood as understanding. In this understanding, information needs to be expressed as signs. Since the relation between signs and objects is arbitrary, signs need to be understood. In that case, the receiver interprets the information by adding meaning to it and the meaning is arbitrary.

Both types of transferring information are sometimes considered as learning. But they are hardly comparable and very different in nature. Thus, it is necessary to distinguish between both types of learning. Unfortunately in our context, the application of computer technology in teaching and learning, both types of transferring information are relevant. This sometimes seems to create a tendency to neglect the difference between both types of information transfer. Usually, the first type is addressed as machine learning and the second type is addressed as human learning. While the word learning occurs in both cases, it does not mean the same term in both cases. Both occurrences are sometimes treated as synonyms, but in fact they are homonyms, since dead people cannot learn and computer technology is dead matter. While transferring information takes place with computer technology, computer technology cannot learn in the sense of human learning.

Thus, our first distinction here is the distinction between transferring information as a copy process that does not require meaning making and human learning that requires the understanding of signs. For clearness' sake we will use learning only in the sense of human learning. What we mean by learning in the following chapters is the communication of knowledge among living beings, and considerably among human beings.

For human beings, learning is an existentialistic problem indeed. It is necessary to learn. Without learning, human beings cannot live. In this context, the subject of didactic is the organized teaching and learning of human beings. While there are quite some and quite different theories about teaching and learning, there is no doubt that humans beings need to be educated. And there is no doubt that they can be creative as well, despite the fact that there are different theories of creativity as well. These two premises, the need to be educated and creativity as basic qualities, are axioms since they cannot be doubted in educational research. Objecting these premises would mean to reject the possibility of education overall.

Starting with these premises and our basic distinction, we are exposing a set of theorems to explicate the educational perspective that was used while developing the INTUITEL approach in this chapter. These theorems are:

1. The future of human beings is open.
2. Human beings can learn to determine themselves.
3. Education is non-deterministic.
4. Education takes place among human beings (generations).
5. Education takes place in a community.
6. Learning processes cannot be observed.

With these theorems, we suggest a theoretical framework to design Adaptive Assistant Systems.

2.1.1 The Open Future of Human Beings

Education is necessary for human beings. But it is not possible to finally predict the results of education [88, 21]. One of the reasons is that human beings are always able to stand up against external influences. They have an own free will. This free will is something that cannot be turned off or overridden. It can be shaped by the context human beings live in, it can be influenced by social interests, other people can try to break it or get it under their control, and we can try to get rid of it, by using drugs, becoming religious fanatics or whatever. Attempts to get rid of the own free will seem to take place if the own free will becomes a burden, which might be the case if human beings are treated as dead matter. But in that case, education is kind of pointless anyway. And the attempt is useless, since it's an expression of the own free will. While we're alive and awake, the own free will is present at all times.

In education, the idea of a free will is often connected to the philosophy of Kant. While details of the relevance of a free will for education are disputed occasionally [33], a free will can't be finally doubted, since doubting a free will already postulates a free will. As a free will is a necessary presumption for education, the cause-effect relations are not suitable to understand education [46].

Since we have to assume a free will at least in some respect, the result of educational processes can't be finally predicated. It is possible to set up educational institutions, curricula, assessment systems, assistant systems, and stuff like that. And it is very much possible to get people to act as if they do not have an own free will in those contexts. But that's it. It's not possible to force people to really judge external influences as meaningful, no matter which motivational strategies, outcome definitions or whatever is brought into educational processes. On the other hand, people sometimes judge content or actions as relevant, even if they are not meant to be relevant. They agree, accept content or actions as relevant, and give it a meaning by making it part of their personality. But due to the own free will, it's not possible to finally predict that acceptance will happen. The only thing we might predict is that people will act as if they accepted it.

Thus, we are facing a fundamental tension among the necessity to be educated and the unpredictable results of educational processes here. This tension indicates the open future of educational processes. The tension between force and freedom is the starting point for our design of an adaptive assistant system.

Besides being open, educational processes are focused on the individual. At least since Comenius has published his didactic in 1657 with "omnes, omnia, omnino" on the title, the individual (and not the average) is important for education. This is necessarily the case, since learning can't be substituted. It's not possible to learn for somebody else. We need to learn ourselves. If somebody else learns something, we do not know anything and as already stated, we cannot just copy the learning results. We need to understand things ourselves. Of course, we can and have to rely on other people's understandings while learning. But to do so, we need to understand that we took the decision to rely on other people's understanding. And obviously, we have to learn how to take a decision like that, and this can't be substituted, since the decision can't be taken by somebody else. If somebody else takes the decision, somebody else will rely on other people's understanding and start to learn. So we can't get out of learning we have to learn and to decide for ourselves. Making meaning is inevitable.

The open future and the focus on the individual make it difficult to prove one teaching method as the very best and the only one for organized teaching and learning. To prove one teaching method as the very best one, it would be necessary to state that it is successful not only in the present, but will be successful in the future. While the prediction of future reactions might be possible with some likelihood in the case of stocks and stones, this is not the case for the behavior of an individual human being. People might decide to act in a predictable way for a while, but sometimes they suddenly change their mind and start to do something different and that's not happening in every century or so. Instead, it can be considered as taking place in anything we do, since we are hardly able to repeat an action exactly as we acted before.

Repeating an action exactly as it was done before might be imagined in a context where only logical operations exist. In that case, we are not facing actions, but something like carrying out orders. To be precise here, not even obeying orders is possible in a context of logical operations, since obeying orders require the possibility to reject orders. But a computer cannot say: "Hey folks, I'm sick and tired of opcode EA, I'm not doing it any more". A computer does not obey instructions. The instructions are just carried out, and they are repeated again and again if required. That's something human beings can't do, even if they want to. And sometimes, they decide to try something completely different instead.

That's why repeatability is hardly ever used as a criterion for scientific truth in the social sciences. We thus have to assume here, that the only certainty, if it comes to teaching and learning methods, is a negative one: It is not possible to prove one teaching method as the very best and only one. Still, teaching and learning methods are possible and might help to get people to act as if they like one teaching and learning method. Teaching and learning methods might also be accepted by human beings, at least temporarily, or in the long run. The criterion for an acceptance in the long run is that people use those teaching and learning methods themselves, that is: The methods are passed among generations. In this respect, educational theories fall into their subject area themselves.

Teaching methods are most often tied to certain research methods. While research and teaching methods are often presented as connected closely (like in [85] or [103], this is always problematic, since no research method can be proven as the eternally right one. The same applies to ethics. In turn, no teaching method, like programmed instruction [30], open learning [90] or pragmatic learning [52] can be proven as the only or best one by scientific research.

If teaching methods and research methods are tied together, teaching methods are connected to certain scientific paradigms [59]. The programmed instruction for example is tied to the paradigmatic experiments conducted by Skinner with pigeons while some theories of learning styles are connected to the Tilting Tests conducted by Witkin [31].

Theories of learning styles illustrate the problem that is at stake here. To show the problem, we have to consider the theories of learning styles as a phenomenon itself. The basic idea of learning style theories is that it is possible to determine people's learning style, present learning material according to the learning style and increase the learning outcome that way. Learning style theories thus assume that learning styles are relatively stable personality traits and that it is possible to predict future learning behavior, since it is necessary to conclude from a standardization procedure in the past to a learning process in the future.

Interestingly, this does not work. There is hardly any evidence for the idea that considering the results of a learning style inventory while designing teaching and learning processes improves learning outcomes [49, 50]. We can suggest three possible explanations for the failure of learning style theories here: First, learning is not influenced by personality traits only. There is a subject area with a certain structure that requires recognition, there are teachers, there is an administration, an institution, a family and so on. All these aspects are considered (consciously or not) by the learner. In other terms: the context matters. This does not mean that context theories are the very best solution. They are just another paradigm.

Second, learners learn how to learn while learning. If we assume that people learn and that learning styles are learned, it does not seem far-fetched to assume that people learn how to learn while they learn considering all that context, their personality and most probably also stuff they will never talk about, however deep you dig into the unconscious. If people learn to learn while they learn, they can do it all the time and thus change their learning style every now and then and it looks like they do it at moments we can't predict.

This might be connected to a third possible explanation. This can be coined as learning to the test. Teaching to the test as a strategy of teachers to prepare students for a standardized test is usually not highly esteemed. But learning to the test is something students do whatever the test looks like. If the test requires some ticks at the right answer, students will prepare for that. And if the test requires some holistic or even critical thinking, students will at least act as if they could think holistically or critically.

It's an interesting argument that they might at least somehow think critically in the second case, no matter what they do: If they accept the requirements of the test, they think critically. And if they only act as if they accepted the requirements, but rejected them instead, they think critically too. In any case, if there is a test, learners usually learn to the test. By doing so, they avoid challenging the procedures and rules of pedagogical institutions, and that's probably a good idea. In turn, this gives some further evidence for the thesis that it is not possible to predict the learning behavior of human beings. Thus, learning styles are no longer termed as personality traits, but as the expression of an individual's analysis of the learning environment by decision making agents.

While the limits and problems of learning style theories have been shown and argued quite often, learning style theories and learning style inventories are still pretty popular. Thus, they are a phenomenon that asks for explanation. But we are not going to suggest a theory of the tempting character of learning style theories or the personality traits of their followers here. Our point is that it is not possible to predict the learning behavior of human beings. Thus, it is also not possible to predict that a certain teaching method will create improved learning outcomes. For the design of teaching and learning environments, playing with multiple teaching and learning methods is more promising than mechanical reactions to test the results.

2.1.2 Learning to Determine Oneself

Play is a cultural phenomenon that appeared all through history. In ancient times, playing games had been considered as not very relevant. It appeared in paintings sometimes, but it is not emphasized as a relevant subject for theoretical discussions. In medieval times, playing games was considered as bad, since it degrades working power and promotes sin and vice [75]. An important change in the perception of games is expressed in Bruegels painting "Kinderspiele" (children's games), which was first shown in 1553. Playing games became considered more as a sphere with a value of its own. The right of people to play was accepted as long as playing contributes to something useful, like the stimulation of mental abilities [75].

This understanding of playing games was picked up in pedagogical considerations by Basedow in the eighteenth century [74]. Basedow suggested to convert all the games children play into something useful. Therefore, Basedow applied games to teach subjects like Latin or Biology. This idea to apply games for teaching something useful is still widespread today, particularly in concepts for digital game based learning [76] or serious games.

At the end of the eighteenth century, the understanding of games was changed and extended substantially. This change culminates in the famous words of Schiller [87]: "Denn, um es endlich auf einmal herauszusagen, der Mensch spielt nur, wo er in voller Bedeutung des Wortes Mensch ist, und er ist nur da ganz Mensch, wo er spielt [For, to finally speak it out at once, man only plays when he is a man in the full meaning of the word, and he is only completely man when he plays]". With this sentence, Schiller identified play as the area where people can become people, and thus as the central place for human development and education.

Schiller discussed this place in the context of arts. He considered arts as a context where human activities have to be understood as play. A necessary condition for this context is freedom, not usefulness. For Schiller, this freedom means being free of being forced by other people's reasoning (kings, priests, etc.) and of being forced by nature (food, housing, etc.). Being free from external forces opens up a room for creative actions, and these creative actions are by no means intended to be useful or profitable.

In our context, the important point is, that play as an existential aspect of human development fundamentally refers to human freedom and the own free will. Due to this, play cannot be controlled from the outside, but only be done by people themselves. This changes the pedagogical perspective in contrast to Basedow. Basedow tried to control learning processes by creating games. With Schiller, playing is understood as an activity that cannot be controlled. Still, playing needs some sort of playground. A room where playing is actually possible is needed, but it cannot be forced that a room for playing games is actually used to play. With Schiller's theory it is possible to understand teaching and learning as a game where people play with content – and where people play with media that are used to learn the content.

2.1.3 Education as a Non-Deterministic Process

Since freedom and the necessity for self-determination are essential parts of education, it's not possible to predict the results of teaching and learning in individual cases. And it's not possible to predict, which teaching activities are appropriate in which situation. Thus, teaching can't be guided by theory only. This problem was introduced by Herbart in 1802 into educational sciences. Herbart differentiates pedagogy into an academic discipline and an artistic practice. Academic theories are derived from principles and made of broad concepts. Artistic practice has to deal with individual circumstances.

While active educational artists (like teachers) like to refer to personal experiences and observations to justify their educational actions, this is – according to Herbart – nothing else than casualness (Schlendrian). Instead, a well-founded theory has to be used to guide observations and experiments. Additionally, Herbart states that studying an educational theory is helpful for guiding the art of education performed by actual teachers. Still, teachers need to act as teachers to actually learn how to be a teacher. In other words: being a teacher cannot be learned from theory alone, but is essentially connected to sharing a common social and, according to Herbart, artistic practice.

This idea of being a teacher is understood by Herbart with the concept of pedagogical attitudes (pädagogischer Takt). Even if the pedagogically acting artist is a profound theoretician, he is not able to consider all his theoretical knowledge while teaching, since he has to act immediately in actual situations. This time pressure makes it necessary to act intuitively while performing pedagogical artwork. Still, these pedagogical attitudes are not considered as everlasting attributes of the personality by Herbart, but as habits that can be changed by theoretical considerations as well as by different experiences. Thus, changing the intuition that is used by teachers is the central objective of teacher training programs for Herbart.

One of the consequences of this concept is, as Herbart points out, that educational actions cannot fully meet the requirements of each individual case. Thus, educational actions always fail at least partly. The possibility to fail is, therefore, a necessary aspect of performing educational actions. While Herbart was convinced that a complete theory of teaching and learning is possible (but not available to him), this conviction is no longer accepted in the educational sciences today. The principle of plurality [80] leads to the conclusion that there is more than one way of teaching and learning in any context.

From this point of view, the debate between behavioristic, constructivistic, instructionalistic or situated learning theories appears rather pointless, since learning actually takes place whichever approach is chosen. The relevant problem is rather to creatively combine objectives, content, methods, and media in a learning environment in meaningful ways. The act of combining objectives, content, methods, and media is understood as theory-practice transformation by Herbart. The theory of the theory-practice transformation indicates a dialectic between thinking and acting. This dialectic problem needs to be considered when designing learning environments with algorithms and data.

Important for us is Herbart's conclusion that the creation of meaningful environments requires intuitive actions, which are based on pedagogical attitudes and guided by pedagogical theories. We suggest understanding this situation as playing a game. The actions in which teachers connect their knowledge about contexts, students, subject matter, didactics, and media are thus understood as ludic actions. Completely theoretically guided actions would require a full theoretical understanding of the situation, unlimited time to analyze the situation, the possibility to reject the action in case of any doubts and a complete knowledge of all participating persons. Obviously, this cannot be the case in education. Thus, educational actions perceived as artistic actions always carry aspects of Paidea [13].

With playful actions, teachers overcome the uncertainty gap – but they have to reckon they might lose the game. If they lose the game, the difference to serious actions shows up clearly: if teachers lose a round, they are not fired, they do not get bankrupt and, of course, they do not die – they just play another round of teaching and learning. And if they are good teachers, they try to play better next time.

At the risk of being boring, we have to repeat an earlier argument here: Dead people do not play. And, as you might have guessed, dead matter is not able to play. Thus, we are facing a problem similar to the initial one here: Computers do not play. Computers can be understood as toys [98], but machines are by no means able to play. Thus, computers cannot act as teachers, but they can be used to create playgrounds where teachers and learners play the game called teaching and learning. Since education in practice always has to take care of individuals, acting as a teacher which is an art form for Herbart. Thus, teachers are artists. And according to Schiller, artists do play.

From this point of view it is obvious, that teaching cannot be controlled or steered by knowledge that can be expressed in algorithms or data. One consequence is that designing an adaptive assistant system is not like designing an industrial robot for serious work. It's more like the creative design of an actual game, like the creation of a room where teachers and learners can play. This might be connected to the difference between game and play that is discussed in video game studies: "Play is an open ended territory in which make believe and world building are crucial factors. Games are confined areas that challenge the interpretation and optimizing of rules and tactics" [102]. Good games foster play, not work to earn one's living.

Games need to consider the rules of the game, while play is a free activity, where freedom is created by open up a make-believe world. Whether play in this sense actually happens cannot be predicted, but we can assume that toys are more likely to be played with than other objects [98]. The media didactical design of a game to be played by teachers and learners needs to consider basic educational problems and the possibilities of algorithms.

One example is the algorithms that have been developed by Brusilovsky et al. [10, 47]. The system developed by Brusilovsky et al. is used to teach Java. The algorithms developed by Brusilovsky and Hsiao allow for setting test question parameters. Questions are calculated. According to test results, links for students are adapted by showing colorful targets. This matches the concept of branched programming.

While this concept is a good idea for an introduction to a programming language, it is hardly possible to calculate variations of test questions that can be analyzed by an algorithm in other fields. Educational theories, for example, cannot be taught that way. Additionally, epistemological questions have not been considered by Brusilovsky et al., since differences among functional, procedural, and object-oriented programming are not taken into account. Different teaching methods are not considered at all. As a consequence, dynamic learning pathways cannot be created. The system offers all information for free navigation and considers the freedom of the learner this way.

But it cannot be transferred into other fields. And it is not possible to design learning pathways that do not contain tests that can be analyzed by an algorithm with this concept.

A second group of concepts applies algorithms that are based on the idea of artificial intelligence and suggest Intelligent Tutoring Systems. It is necessary to say a word on the term artificial intelligence from an educational point of view here. First, as we already stated for learning, intelligence in the term artificial intelligence has another meaning than intelligence in the term human intelligence. Second, human intelligence has a different meaning than the term thinking in philosophy, while thinking does not mean the same as understanding or learning in education. What is comparably clear is the definition of the term algorithm [58]. Considering the definition of algorithms it is clear, that neither understanding nor learning has anything to do with artificial intelligence.

Intelligent tutoring systems are based on algorithms. They are connected to the shift from batch processing to dialogue systems and problem solving theories. Additionally, extended computational power is used to Intelligent Tutoring Systems. The idea was first based on the concept for the General Problem Solver (GPS) [71], where the knowledge of problems and strategies to solve problems were separated. When the GPS failed for any relevant problem, the concept was replaced by expert systems [26]. The core architecture of the DENDRAL expert system [11] (knowledge base, explanation system, inference engine) became the starting point for SCHOLAR [12], which was built as a semantic network and based on the architecture of expert systems.

2.2 Computer Technology as a Medium in Teaching and Learning

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We understand media as things that are used as signs by human beings. With this broad term of media it is clear, that media need to be applied in all educational processes. This starts from the body in the medium of a gesture and reaches through oral communication to technical appliances like books, TVs or a computer.

From the different aspects of our media theory we would like to highlight one aspect here: Technical media are artifacts, and human beings express themselves in these artifacts. This describes a layer of communication, where the material of a medium is shaped in order to exchange ideas. This layer of communication has been highlighted by the Toronto School [48, 64]. Since using material in a medium is necessary for communication, this layer affects educational processes. In educational processes, it is impossible to avoid the bias of communication caused by the material layer, but necessary to choose or, if it comes to technical media, shape the material layer of the medium used.

Here, it is not possible to discuss criteria (like the interest in acceleration, individualization, etc.) for choosing or rejecting computer technology as a medium in educational processes. We just assume as obvious that it is possible to teach and learn with computer technology and describe the material layer of computer technology in order to inform the design of our tools.

Computers today are nearly always built as electrical universal Turing machines with a von Neumann architecture. This design of the material layer of the medium leads to a set of properties. One important property is that computers need to be programmed. Programming a computer is quite different from educational processes among human beings. The program determines the output of the computer, even if stochastic measures are used. That's why transferring information between computers has a very different meaning than learning in the field of education, as we already stated. We would like to add three observations to take a closer look at computer technology here.

The first observation is that the memory of human beings and the data storage of computer technology are quite different. Human beings can't forget. Of course, human beings do forget. But this is something that happens to human beings. It is not a competence. There is no "mastery of forgetting". To the contrary: The harder humans try to forget something, the better they remember it. Deleting data with computer technology is quite different: It can be executed on purpose. And it can be done sustainably.

The second observation is that there is an exact alignment among assembler commands and machine code in digital electric Turing machines. Since the meaning of machine codes in actually is the physical reality of the actual machine, there is no difference between symbols and reality for computer technology [58]. As René Magritte has illustrated with the words "Ceci n'est pas une pipe" on his famous picture "La trahison des images" [The Treachery of Images], this is not the case for human beings. For people, the relation of symbols and reality is problematic – to say the least. That's one reason why human beings become problems for themselves. Fortunately, this is not the case with computer technology.

These observations illustrate that the term "learning" signifies different concepts in computer technology and in education. The difference between these homonyms is the challenge when it comes to modeling didactic expertise with computer technology. With this challenge it is clear, that trying to replace teachers by computer technology is not an option. Machine learning and human learning cannot be converted; there is no jumper to close the open gap. That's why we consider computer technology as a valuable tool that can be used to design an adaptive assistant system for teaching and learning. From the media didactic point of view, the challenge is to create applicable algorithms and thus design the material substance that is used in the medium. Until now, we tried to elaborate some limits of the application of computer technology in education. With this in mind, we are going to discuss the history of Adaptive Assistant System in the next section.

2.3 The History of Adaptive Assistant Systems for Teaching and Learning

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When designing an adaptive assistant system for teaching and learning, a look at the history of these systems is informative. One of the interesting aspects is the impact of programing techniques that were fashionable at a time on the conceptualization of adaptive assistant systems.

If feedback is considered as a criterion for automated support in learning, the device presented by Pressey in 1923 was the first teaching machine In his paper, Pressey [77] stated that the device should not replace the teacher, but "make her free for those inspirational and thought-stimulating activities which are, presumably, the real function of the teacher". Skinner [92], who picked up Pressey's design as well as the foundation in the theory of Thorndike, also considered this limitation of machine support in learning. While Skinner applied feedback mainly as reinforcement in linear learning programs, Crowder's setting of intrinsic or branched programming offered a different feedback. His machine generated an individualized learning pathway [20] when a learner failed a test in a way that reflects the development of block-structured programming languages. The different learning pathways included additional content and explanations concerning the error, while individualization did not mean that the learner could make choices of his own.

This concept has become famous under the label programmed instructions [30] and is still used often. The concept is mainly based on tests that can be analyzed automatically. Today, this concept is called adaptive since current applications adjust the amount of tests, the available time for learning, the difficulty of questions, waiting times and hints while learning [53].

This first individual learning path component was extended by adaptive systems in the 1960s and 1970s [72]. Adaptive systems added a more sophisticated dialogue component to the programmed instruction systems and thus reflected the development of dialogue systems. This concept of adaptive systems is still developed today [34]. From a present-day perspective on programmed instruction, the connection between the actual machines and the theoretical concept is obscure on the one hand and many charges against behavioristic concepts are hardly sustainable on the other hand [52]. Maybe the second argument explains why behavioristic concepts are successfully applied in therapy today, but hardly in teaching and learning.

One example is the algorithms that have been developed by Brusilovsky et al. [10, 47]. The system developed by Brusilovsky et al. is used to teach Java. The algorithms developed by Brusilovsky and Hsiao allow for setting test question parameters. Questions are calculated. According to test results, links for students are adapted by showing colorful targets. This matches the concept of branched programming.

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In this concept, limitations were hardly considered, and learners could only barely make their own choices. Despite the effort invested in ITS there are hardly actually working systems available or real world applications reported. ITS seems to have failed due to the high effort necessary to develop such systems and the lack of theoretical foundations [91]. From our perspective, considerably basic educational problems like the theory-practice-transformation were not considered in the design of ITS.

In the last years, the successful application of recommender systems in marketing led to the idea of transferring the concept of those systems in the didactic field [23]. This often takes place in the context of informal learning processes [62]. The concepts seem to be related to constructivistic learning theories, while explicit references are rare. While most of the suggested systems are in the early stages of development, the expectations are high. At least, these expectations appear to be similar to the systems discussed before. Since the difference of marketing and didactics is not considered yet for recommender systems, similar problems can be expected as well.

With systems for programed instruction, intelligent tutoring systems, adaptive learning environments, and pedagogical recommender systems concepts for automatic educational reasoning have been developed. These systems haven been developed for many decades. Despite the effort invested there are hardly actually working systems available or real world applications reported. Intelligent tutoring systems seem to have failed due to the high effort necessary to develop such systems and the lack of theoretical foundations [90]. This might be connected to one concept all the systems developed so far share: Developers assumed that learning is a formally describable and controllable process. Fortunately, this assumption is wrong.

Neither the General Problem Solver nor the Intelligent Tutoring Systems that were based on the General Problem Solver were useable or successful. [90]. This applies to current systems that are based on the same concept too. One example is the concept developed by Bredweg and Struss [9]. Based on an overview on qualitative reasoning they show that the strength of qualitative reasoning is the consideration of causality. They argue that this consideration of causality is a strength of the approach, since causality is essential for model building in scientific thinking. As a conclusion, they focus on the presentation of cause-and-effect-chains in artificial intelligence algorithms. This presentation is turned into educational objectives. Learners should learn the cause-and-effect-chain thinking by modeling causal relations with cybernetic qualitative intelligent algorithms.

That way, only one epistemological concept is considered. Unfortunately, this is not explicit – the epistemological position is not discussed by the authors. A reference to the theory of modeling [94] order representation theory [104] is missing as well. By doing so, the freedom of the learner that is connected to choosing an epistemological position is neglected. Since the necessity to reflect scientific methods is neglected as well, the approach can hardly be understood as scientific thinking. It is focused around the idea of an operative cybernetic control system. Since such a system is based on algorithms, it creates a self-contained world [58] and thus the illusion of a predictable and known future.

Another approach is algorithms that conduct tests of learning styles and present content accordingly. One example for a study like that has been published by Lehmann [60]. It is based on the learning style inventory developed by Kolb [56]. Content has been prepared for a learning cycle that allows for the consideration of learning styles [60]. Learners have been tested. They were randomly spread on treatment groups so that the content was presented in a way optimized due to the results of the learning style test.

This study shows several problems: First, the research by Lehmann was based on a small incidental sample from a small basic population. The results can thus not be generalized. Second, there were hardly any relevant results. This is not astonishing, since designing content based on learning style inventories, that is on a perspective based on averages was not successful before [49, 50]. From a didactic perspective this was expected, since learning style theories do not take into account that learners do not learn content only, but also learn to learn [99], as we already stated.

The first adaptive systems have been developed in the 1960s and 1970s [73]. One contemporary example for an adaptive system is the approach suggested by Martens [63]. Marten's Tutoring Process Model (TPM) is a formal approach to the design of Adaptive Tutoring Systems. A prototype based on the concept has been developed. The prototype is not available anymore and has not been used in other projects. This is a faith shared by many prototypes in the field of didactics [90].

Martens defines the tutor model as $TPM =< C, LM, show, enable >$ with $C =< Q, A, q0, F, B, \delta, select, allow >$ and

Q: finite set of states
A: finite set of actions
$q0 \in Q$: start state
$F \subset Q$: finite set of final states
B: finite set of bricks
δ: state transition function
$select$: select brick function
$allow$: select action function.

With this definition, building adaptive menu systems becomes possible. A learner model can be considered formally. Only elements to inform and to interact are considered as building blocks. Cooperations are missing. This limits the possibilities of the model. Similar limits exist in other models [14].

It can be concluded that educational problems are not sufficiently considered in the discussed approaches. The algorithms are limited to isolated cases and small content areas like Mathematics, Programing and Languages. In nearly all cases only standardized parts which are located at the beginning of curricula were considered. Many algorithms that are developed today fall behind the approaches discussed. They only use simple versions of programed instruction. In some cases successful applications in certain subject didactics have been created. But none of the approaches designs the leeway in the communication among teachers and learners by considering media didactics.

Another point is that computer technology is neither capable of creating art nor able to play. Thus, computer technology can never replace teachers. Maybe it can simulate learners that make teachers happy but this has hardly been researched yet.

2.4 Conclusions

The argumentation in the first sections leads to a different status of Adaptive Assistant Systems. While previous concepts tried to replace teachers, we try to create tools for teachers. These tools are intended as toys that suggest teachers to play with their teaching methods and the media they apply. If teachers play with teaching methods and media and offer differences and varieties, they again open up a playground where students can learn while playing with these teaching methods and media.

Based on this perspective, designing an Adaptive Assistant System places us in the position of designing tools for creating games. These tools can be used to create a playground for teachers that act as artists who create games for learners. Pictorially we create brushes and colors that are used by teachers to paint pictures that are shown to the learner. Thus, the challenge is to design tools for the creation of teaching and learning processes that open up spaces for creative actions. The fact that the contradiction between compulsory rules and open creativity is solved without any problem, while actually playing games and shows in turn that the association of gaming for teaching and learning is suitable.

It is obvious that a supplier of brushes and colors has hardly any control about the created artwork that will be presented to the audience. The only thing he can assume is that the color will be present in the artwork in which form ever. This is considerably the case if you think about something like audience participation in non-scripted performance art. Since we consider Adaptive Assistant Systems as tools for teachers and not as a replacement for teachers and according to Herbart acting as a pedagogue is an art form it does not make any sense for developers of Adaptive Assistant Systems to even try to control learning environments and learning outcomes above all. A consequence of this is that learning outcomes cannot be applied as a measurement for a successful design of an Adaptive Assistant System. Still, this measure has been applied as the only measure in recent decades. Thus, it is necessary to develop new criteria for the success of Adaptive Assistant System. We assume that human beings do have an own free will, need to live in a community, and need to be understood as decision making agents. Freedom and the open future are considered as essential. Starting with this assumption, the possibilities and limitations of computer technology in teaching and learning have to be considered.

If the possibilities and limitations are considered, computer technology can be used as an assistant system for teachers and learners. Since computer technology needs to be programmed, programmers have to be considered as teachers that set up the setting in which other people teach and learn. In this respect, their actions can be understood as a kind of policy making for teaching and learning. Designing, implementing, and deploying software for teaching and learning is an educational act. Since the software is usually used as it is, software is an instrument to claim power.

In this respect, the balance of force and freedom as a basic educational problem needs to be considered. The developing freedom of learners has to be taken into account. From an educational point of view, the software for teaching and learning has to be designed in a way that suggests and allows learners to develop their freedom. This can be done by offering learners' tools to increase control on their learning processes. Of course, this is a claim to power again and refers to the basis dialectic of freedom and force that is inevitable in education.

Instruments that support learners' control can consider the content and the learning process. Since our project aims at a content independent software, the learning process can be taken into account only. To do so, data about the learning process have to be collected and analyzed. The results have to be turned into recommendations for the learner. If the recommendations reproduce teachers input only, they are pointless. Adaptive Assistant Systems become relevant for education if they support creative behavior by the learner and thus support learners to create their own way of learning.

In INTUITEL, this is applied to Learning Pathways and Feedback. Learners should be supported in choosing from different learning pathways and in creating their own learning pathways. Feedback can be created by considering learners earlier behavior and by considering other learners' behavior. This again can be used to create recommendations only. It has to be possible that learners deviate from recommendations issued by the software.

Finally, the freedom of teachers has to be considered as well. It has to be possible to express different content structures and arrange content according to different learning theories. At the end, it is necessary to include the possibility for teachers to try to force learners to learn in a certain way, while we cannot predict which way this will be. Thus, a structure to allow teachers to express different ideas of teaching is necessary too. These requirements can be matched by reasons that are applied to dynamic hypertexts which are based on a didactic ontology and the collection of data about teachers and learners. In other terms: INTUITEL is about ontologies and reasoning in education.