3

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. Forth, conclusions from these preliminary thoughts are drawn.

3.1 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 can not 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 can not learn and computer technology is dead matter. While transferring information takes place with computer technology, computer technology can not 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 can not 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 can not be doubted in educational research. Objecting theses premises would mean to reject the possibility of education at all.

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 can not be observed.

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

3.1.1 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 can not 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, 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 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 can not 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. Meaning making is inevitable.

The open future and the focus on the individual makes it difficult to prove one teaching method as the very best and 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 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 requires the possibility to reject orders. But a computer can not 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 pragmatistic 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]. 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 ding 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 than 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 to challenge 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 long term personality traits, but the expression of an individual 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 the 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 behaviour 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 results.

3.1.2 Learning to Determine Oneself

Play is a cultural phenomenon that appeared all through history. In ancient times, playing games has 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" (childrens games), which was first shown in 1553. Playing games became more and more considered as a sphere with a value of its own. The right of people to play became 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 18th century [74]. Basedow suggested to convert all 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 18th century, the understanding of games was changed and extended substantially. This change culminates in the famous words of Schiller: "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]" [87]. 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 peoples 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.

3.1.3 Education as a Nondeterministic 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 can not 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 can not 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 to understand 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 can not 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 can not 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 for individuals, acting as a teacher 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 can not 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 ones 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. Wether play in this sense actually happens can not 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 are 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 algorithms in other fields. Educational theories, for example, can not 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 can not be created. The system offers all information for free navigation and considers the freedom of the learner this way. But it can not be transferred into other fields. And it is not possible to design learning pathways that do not contain tests that can be analysed 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 build as a semantic network and based on the architecture of expert systems.

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