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A Pedagogical Ontology as a Playground in Adaptive Elearning Environments

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Abstract: The support for teaching and learning with semantic technologies and intelligent knowledge processing has been approached by four concepts: programmed instruction, adaptive learning environments, intelligent tutoring systems, and educational recommender systems. While the demand for automated support in teaching and learning is estimated as high, the use of developed systems is observably low. With reference to educational theories, this paper argues that one reason for this is an overestimation of the possibilities of such systems. Considering the limitations of automated systems in human communication as a constraint, a pedagogical ontology as a description language is proposed that opens up an educational playground for teachers and learners.

1 Introduction

If feedback is considered as a criterion for automated support in learning, the device presented by Pressey in 1923 was the first teaching machine [Be88]. In his paper, Pressey 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" [Pr23]. Skinner, 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 [Sk58].

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 individualised learning pathway [Cr77] when a learner failed a test. The different learning pathway included additional content and explanations concerning the error, while individualisation did not mean that the learner could make his own choices.. This first individual learning path component was extended by adaptive systems in the 1960s and 1970s [Nw 90]. Adaptive systems added a more sophisticated dialogue component to the programmed instruction systems. The concept of adaptive systems is still developed today [GR11].

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 behaviouristic concepts are hardly sustainable on the other hand [KW02]. Maybe the second argument explains why behaviouristic concepts are successfully applied in therapy today, but hardly in teaching and learning.

Extended computational power and general problem solving theories lead to the idea of intelligent tutoring systems (ITS). The idea was first based on the concept for the General Problem Solver (GPS) [NSS59], 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 [FE81]. The core architecture of the DENDRAL expert system [Bu71] (knowledge base, explanations system, inference engine) became the starting point for SCHOLAR [Bu89], which was build as a semantic network and based on the architecture of expert systems. In this concept, limitations were hardly considered, and learners could only barely make own choices. Despite the effort invested in ITS there are hardly actually working systems available or real world applications reported. ITS seem to have failed due to the high effort necessary to develop such systems and the lack of theoretical foundations [Sc07]. In the last years, the successful application of recommender systems in marketing led to the idea of transferring those systems in the didactical field [Du11]. This often takes place in the context of informal learning processes [Ma11]. 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.

In concepts mentioned, systems are developed on the basis of psychological theories about intelligence and learning. They are never based on philosophical ideas of thinking or educational concepts of reason, which build the basis for didactical theories. From an educational perspective, the systems are thus designed according to short sighted concepts. While considering philosophical concepts of thinking is behind our scope, we suggest to consider the theory of Herbart as a first educational concept. With this concept, we suggest a different way to think about the role of computer technology in teaching and learning and a corresponding pedagogical ontology as a description language for educational content.

2 Theory-Practice-Transformation

One of the fundamental problems for pedagogical theories is the theory-practice- transformation. This problem was introduced by Herbart in 1802 [He82]. Herbart differentiates education as an academic discipline and as 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 really 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, she is not able to consider all her theoretical knowledge while teaching, since she has to act immediately. 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, but as habits that can be changed by theoretical considerations as well as by different experiences. 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. This is hardly considered in the concepts mentioned before.

While Herbart was convinced that a complete theory of teaching and learning is possible (while not available to him), this conviction is no longer accepted in the educational sciences today. The principle of plurality [Re99] 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 behaviouristic, constructivistic, instructionalistic or situated learning theories appears rather pointless, since learning actually takes place whichever approach is chosen. The relevant problem is rather to combine objectives, content, methods and media in a learning environment in a meaningful way. What meaningful means in this context refers to philosophies of education and can not be discussed here. Relevant is Herbart's conclusion that the creation of meaningful environment requires intuitive actions, which are based on pedagogical attitudes and guided by pedagogical theories.

In this paper, we propose to understand this situation as playing a game. The actions in that teachers connect their knowledge about contexts, students, subject matter, didactics, and media is thus understood as a ludic action. Completely theoretically guided actions would require a full theoretical understanding of the situation, unlimited time to analyse the situation, the possibility to reject the action in case of any doubts and a complete knowledge of all participating persons. This is hardly ever the case in pedagogy. Thus, educational actions perceived as artistic actions always carry aspects of Paidea [CA58]. With playful actions teachers overcome the uncertainty gap - but they have to reckon they might lose the game. In the later case, 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 the next time.

The problem is: Computers do not play. Computers can be understood as toys [Sw99], 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.

3 A Pedagogical Ontology as a Playground for Teachers and Learners

Understanding teaching and learning (at least partly) as play and computer technology as a toy used to create a playground sheds some light on the position that is taken when creating a pedagogical ontology for machine support in didactical practice: we are creating a game for people who play a "create a game" game. With computer technology, the playground can be best modelled by an ontology [Ne91]. This form of a semantic network specifies the rules of the game.

In order to do so, it is necessary to open up different possibilities for expressing ideas of teaching and learning creatively. Still, some rules have to be set when creating games. In order to keep the possibilities open, these rules can be developed from an analysis of computer technology as a medium, since the properties of a medium applied in teaching and learning always limit the possible actions.

An ontology needs to be consistent from a technical perspective [Gr95]. In contrast, teaching and learning is inconsistent due to the artistic nature of educational actions. Thus the challenge is to build an inconsistent consistency, that is an ontology that opens up a consistent room which is necessary to meet the logical structure of computer technology an that allows for the creative design of teaching and learning processes. The gap that is indicated by this contradiction can be filled by teachers and students when playing with the system.

The consistent part of the ontology we propose consists of a three level meta data system for learning objects [Me06]. Learning Objects include instructional scaffolding such as learning objectives and outcomes, assessments, and other instructional components, as well as information objects [Metros, 2002]. We accommodate the levels of learning objects by using three types of Learning Objects: (1) Knowledge Domain (Course Level), (2) Concept Container (Lesson Level), and (3) Knowledge Objects (Content Level).

The term Knowledge Domain refers to a certain amount of knowledge, which is defined by a specific curriculum, syllabus and/or course requirements. One Concept Container contains one instructionally framed concept within a Knowledge Domain. A Concept Containers is a container for one or more Knowledge Objects (KO). A Knowledge Object is an item of knowledge, which typically corresponds to about one screen page of content and to an estimated learning time of 3-10 minutes for the average learner. A KO might contain learning content as well as learning activities such as a discussion in a forum, an assignment where a video has to be handed in or reading an explanation. Knowledge Objects are described by a pedagogical knowledge type and a media type.

Concept Containers and Knowledge Objects can be connected by relations. In order to support different learning pathways, a vocabulary has been developed. The vocabulary for the Concept Containers is intended to express the structure of the knowledge domain. It considers the hierarchical relations has child, has parent, and has sibling as well as the chronological relations is before, is after and is beside. With these relations the logical structure of the learning pathways bottom up, top down, chronologically forward and chronologically backward can be expressed in OWL. The vocabulary for the knowledge types is intended to express pedagogical concepts. To support the expression of different pedagogical concepts, it consists of the relations isBeforeStructuredInquiryBased, isAfterStructuredInquiryBased, isAfterGoodPracticeMultiStage, isBeforeGoodPracticeMultiStage, isAfterSimulatedMultiStage, isBeforeSimulatedMultiStage, isAfterOpenInquiryBased, isBeforeOpenInquiryBased. With this relations, multi-stage learning for simulations and good practices and inquiry-based learning in an open and a structured version can be expressed. The vocabulary for the media types is also intended to express pedagogical concepts. It consists of the relations isMoreAbstractThan and isMoreConcreteThan. With these relations, an abstracting and a concretisising learning pathway can be expressed.

With these relations, 4x4x2=32 different learning pathways can be designed. Still, these learning pathways are only a small excerpt from educational concepts for teaching and learning. Because of this restriction and to consider the idea of shaping a playground, the three level meta data system offers a consistent structure, while this it not the case for the vocabulary we suggest. The vocabulary used to describe the concept containers and the knowledge objects as well as the relations between the concept containers and the relations between the knowledge objects can be altered by authors. Additionally, the relations can creatively be applied to learning objects. A didactical designer is, for example, not forced to use the steps that are described in the inquiry-based learning theory. She might mix some steps from multi-stage learning into the inquiry-based learning pathways, thus creating a new learning pathway. She might even add new relation types to express more different learning pathways. For learners, these different learning pathways open up a playground since they can follow teacher recommendations (issued by the intelligent component of an adaptive system) or use the meta data as a navigation tool to invent their own learning pathways. This in turn can be identified by automatic reasoning and later on offered as a personal learning pathway to this learner, who thus plays with the automatic reasoning engine.

4. Conclusions

The consistent inconsistency of the pedagogical ontology opens up a playground for teachers and learners. Thus teachers and learners can play with educational concepts. The ontology is developed for and will be implemented in the INTUITEL system (www.intuitel.eu). INTUITEL will be a tool that allows teachers and learners to foster agreement in the communicate about a domain specific ontology (expressed in content and cognitive model). Additionally, a reasoning engine will be added and used to compute recommendations for the learner. Playing with the content and the pedagogical intentions expressed in the learning environment suggests to reflect on the pedagogical process. This reflection can be understood as an occasion for self-reflection and thus for developing identity.

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