ENHANCING THE TUTOR MODEL OF INTELLIGENT TUTORING SYSTEMS

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Abstract
Intelligent Tutoring Systems are systems that have general features that can communicate with a student, define the student knowledge and abilities, and can change the teaching strategy. Teaching strategies employed in intelligent tutoring systems, as usual, are not based on old and recent developments in pedagogical science and ignoring both general principles of teaching and learning theory and many classical teaching methods suggested by practicing teachers. This paper describes the use of traditional theories of teaching and learning, in terms of enhancing the tutor model of intelligent tutoring systems.

Keywords:
Intelligent Tutoring Systems (ITS), theory of teaching and learning, teaching strategy, tutor model.

1. INTRODUCTION

One of the most prospective and advanced directions in the field of designing of computer-based tutoring is the development and designing of Intelligent Tutoring Systems (ITS).
Knowledge about a student is one of the knowledge types that are used by a tutor in the teaching process and are necessary for designing "intelligent" tutoring systems. To support "intelligent" teaching process a tutor uses special knowledge of three main types: subject matter, teaching strategy, and student. To these special types of knowledge we can add the student ability to communicate: to tell, to show something to a student, to understand his answer. In ITS the necessary knowledge is explicitly marked and presented, as a rule, with the help of various methods and technologies of knowledge engineering. Using this knowledge ITS are capable to implement various functions of a tutor (to assist in the process of task accomplishment, to identify the reason of student's mistakes, and to choose the optimal educational step).
Intelligent Tutoring Systems (ITS) are systems that have universal features, which can communicate with a learner, can define the student knowledge and abilities, and can change the teaching method so it can be personalized. ITS attempt to capture a method of teaching and learning represented by one-to-one human tutoring interaction.
A review of the recent literature on ITS shows that not much has changed since the 80's with regard to the structure, design or methods used to create intelligent tutors (Anderson et al., 1985; Capell and Dannenberg, 1993; Mark and Greer, 1993; Murray, 1999; Poison and Richardson, 1988; Shute and Psotka, 1996; Sleeman and Brown, 1982; Wenger, 1987). Generally, intelligent tutors have the following components:

- domain model
- student model
- tutor model
- interface

The domain model refers to the topic or curriculum being taught, which contains facts, procedural, and other knowledge of a subject matter (Siemer and Angelides, 1998; Thaw and Somnuk, 2005). The student model refers to the student or the user of the ITS, which is constantly updated in the teaching course in accordance with the changing characteristics of a student it reflects. Such a model is used by all system modules to adapt their work to a particular student (Beck et al., 1996; Siemer and Angelides, 1998). The tutor model refers to the methods of instruction and how the material shall be presented, which is presents the knowledge of an expert-pedagogic about organization and support for the task-oriented teaching process. Based on teaching strategy and taking into account a student model the tutor model provides for the management of teaching activity (Beck et al., 1996; Freedman, 2000; Thaw and Somnuk, 2005). The interface allows communication between the student and the other models of the ITS, which is containing the knowledge that is necessary to support interaction with a student. This model provides for the communication with a student in a convenient and understandable form and also converts questions and answers of a student in the form accepted by the other models.

A student learns from an ITS by solving problems. The system selects a problem and compares its solution with that of the student, and then it performs a diagnosis based on the differences. After giving feedback, the system reassesses and updates, the student skills model and the entire cycle is repeated. As the system is assessing what the student knows, it is also considering what the student needs to know, which part of the curriculum is to be taught next, and how to present the material. It then selects the problems accordingly.
This paper is structured as follows: First, we demonstrate an overview of ITS components, followed by ITS classification. Then the teaching and learning theories description. Then results and discussion are presented. Finally, we provide a conclusion.

2. CLASSIFICATION OF ITS

In the literature various types of ITS classification are mentioned (Petrushin, 1992; Soroko and Zhuravlev, 1992). Most often they are classified by their purpose in the teaching process. The classification of ITS in accordance with their goals (Petrushin, 1993):

- Consultation (Teaching through experimentation)
- Diagnose (Error diagnosis for task solutions)
- Management (Teaching concepts and abilities (skills) based on student's knowledge modeling)
- Companion (Tracking the user's actions and help him in case of erroneous or irrational actions)

Consultation type of ITS represents a system designed for teaching by means of experimentation. The teaching is carried out in the process of active interaction with a certain, in a special way prepared, teaching medium. A student when experimenting with a medium tries his ideas and hypothesis and receives in response answers.
Diagnose system is intended to detect a student's misconceptions of a subject matter, as a result of which he commits errors when solving a certain type of tasks. Diagnose type of ITS is composed of interface, task solution expert systems, error diagnosing expert system, and a student model.
Management system is designed to control and manage the cognitive activities of a student. Management type of ITS contains all components that are shown in the figure 2, with distinguish concepts of teaching and abilities (skills), corresponding programs are called teaching and training programs. In spite of all this, the main difference of teaching programs from training programs is the presence of goals of study for new material in the teaching programs.
A companion system is designed to monitor a user's activity when the user is working in a certain (tools) system and to assist him in detecting erroneous or irrational actions. A companion type of ITS tries to understand what a user is doing, to assess how the user is doing this and make a decision, whether it is necessary to help him, and if yes then how to provide this assistance. A companion type of ITS contains all components of ITS but unlike a management type of ITS it:

- does not know the goal of a user's activity and has to forecast, which expands the functions of the system in terms of errors diagnosis;
- is less communicative as not to distract a user from his work.

3. TEACHING AND LEARNING THEORIES

A comparative analysis of the existing ITS (Boulay and Luckin, 2001; Capell and Dannenberg, 1993; Hatzilygeroudis and Prentzas, 2004; Rosenberg, 1987) and methods of tutoring showed that, in general, ITS do not take into account individual cognitive characteristics of a student. Usually such a system assesses the level of knowledge, and rarely – it divides students into several main types by progress. There is a lack of adaptation of forms and methods of knowledge presentation according to cognitive preferences. Additionally, strategies of teaching used in ITS, as a rule, are:

- not based on the achievements of the pedagogical science;
- not adaptive, do not contain a diagnostic component and cannot automatically concord to the personal characteristics of a learner;
- implemented as a scenario containing teaching material. Such a scenario requires a strict preplanning of dialogue behavior of a student and a tutor. This, in turn, does not allow for effectively consider of user's cognitive characteristics.

While teaching strategy (tutor model) represents one of the four basic components of ITS, authors of systems described in the literature generally ignore findings from research in teaching and learning processes.
Providing a methodological basis, teaching and learning theories should have to be applied in teaching strategy design. To date, however, instead of a complete and formalized system, the teaching and learning theory rather exists as a set of relatively isolated units (Draper, 1994):

- Teaching and learning philosophy;
- Teaching substance;
- Learner and learning material relationships;
- Teaching and activities.

3.1 Teaching and Learning Philosophy

The teaching and learning philosophy is discussed in the literature in the following trends: structuralism, constructivism, activity-orientedness learning, and multi-link teaching.

In a more general case, *structuralism* can be described with the central idea of knowledge existing as multiple "chunks" or fragments, rather than a homogeneous structure. Another distinctive feature is the juxtaposition of knowledge structure, and their use and representing. Structure thus appears as more important than the way of representing. Obviously, the author's adherence to structuralism is reflected in the strategy advanced. For instance, knowledge conceived as fragmentary, will produce the "teaching episode" strategy. Moreover, the concept of fragmentary knowledge will easily take us to the concept of a fragmentary teaching process (Rumelhart and Norman, 1978). Whereas a non-structuralist researcher expects that all parts of unknown material are learned with equal facility (or difficulty), the structuralist believes that different mental efforts are required, depending on whether the student should create a new mental model, or modify or supplement an existing one.

The term of *constructivism* is heavily used today in discussing of educational problems in general, and teaching strategy design in particular. Constructivism means a position implying that human knowledge depends on two interacting factors: external (teaching) stimulus and preceding mental experience. The proposition of learning governed by previous mental experience is central in teaching and learning theory. Constructivism can be regarded as a theory fitting between two extremes: cases of external stimuli acting as governing factors and adequate knowledge transmission mechanism, and cases of dominating previous mental experience and inadequate transmission model. *Constructivist philosophy maintains that teaching is not the only cause for learning* but rather one of such causes, acting as external teaching stimuli. Simplified constructivism denies the necessity and possibility of learning through knowledge transmission, suggesting exploring the subject of learning from past mental experience as the unique learning method.

Activity-orientedness learning addresses the following problem: "Should the learner act on material to be learned, or should passive perception suffice?" Some constructivist researchers believe that the idea of constructivism implies a positive answer to the question, maintaining that learning progress depends on the degree of learner's activities with regard to material to be learned (Von, 1984). However, this perspective appears as conforming to simplified constructivism and open to discussion. Without denying the role of learner's activity with material in question, attention should be drawn to cases of knowledge transmission accomplished without any noticeable activity. It is conceivable that activities are required for several reasons: insufficient passive perception for understanding, and learning time limits.

Forgetting constitutes a fundamental property of human memory. The most mysterious fact relating to the phenomenon of forgetting is the absence of any evidence of forgetting as biologically essential and providing human evolutionary advantages, like e.g. memory resources to accommodate new knowledge. On the other hand, there is some evidence of the human memorizing total (or almost total) information obtained before. A lost portion, due to forgetting, can be reconstructed either in part or whole. Bartlet (1932) demonstrates that reconstruction is a fundamental and comprehensive property of human memory, determined by the strength of *multiple links* associated with the concept to be reconstructed. This fact underlies the learning principle of more links of learning material with past knowledge implying more chances of the material to be learned, memorized and, subsequently, reconstructed. Obviously, multiple links would not be so important if human memory had no forgetting property.

3.2 Learning Substance

Learning substance is discussed in the literature on teaching and learning in terms of: declarative and procedural components relationships in teaching; and socially distributed nature of knowledge and group (school) learning.

Activity-orientedness learning does not mean preference to procedures rather than concepts in learning. According to Piaget's Theory of Intelligence (Brainerd, 1978), concepts or declarative knowledge result from generalization in activities, with their learning considerably enhancing learner's procedural knowledge. A chess experts, for instance, demonstrates a high level of procedural knowledge, representing in serial moves, only relying on experience stored as declarative knowledge. The essence of all academic subjects in all disciplines lies in *description rather than sensomotoric personal experience*. *Thus academic knowledge is primarily knowledge of descriptions*. At least in academic education, activity-orientedness learning should be primarily interpreted as activity oriented on description rather than physical actions with learning subject.

Human knowledge and, consequently, potential teaching subject, is socially distributed in the sense of their common semantic interpretation for all. Putnam (1975), investigating the phenomenon of social distribution of knowledge, emphasizes the role of common communication language exemplified in words like "water" or "gold" that have, or should have, a common meaning for most people.

School education maintains a widespread conception of knowledge to be tested in formal examination, believing in methods preparing a pupil for successful examination tests as all-purpose teaching mechanisms. Investigations in school education reveal some distinctive features (Scribner and Cole, 1973). The principal conclusion is that school education exists out of context, thus being context-free, generalized and abstracted. School teaching develops specific skills for school culture (for example, remembering material during testing).

3.3 Learner and Learning Material Relationships

The learner and learning material relationships are discussed in terms of the two problems: learning motivation and routine problem selection by the learner.

Many psychological theories and cognitive models applied in the theory of teaching and learning (behaviourist, SOAR, etc.) ignore motivation, thus implying that motivation has little or no effect on learning. This means that teaching is uniform, inevitable, and irrespective of the learner's desire. Nevertheless, while exerting little effect in early childhood, motivation provides a major learning factor for adults. A grownup individual will be little interested in irrelevant material, while demonstrating superior efficiency with material conforming to his/her interests. *Motivation can be interpreted as learner's readiness for mental effort*. Thus motivation will offset the expected nuisance of required mental effort in learning new material.

In the case of dominant mental experience, constructivist philosophy suggests an independent learner navigating in the learning environment and therefore solving a routine selection problem. The importance of this selection problem for the teaching and learning problem at large, and the constructivist approach in particular, is attested by the fact that, in some cases, it is described as a special teaching principle (Draper, 1994). If routine selection is deliberate rather than arbitrary, it means that *learner's mental experience involves a learning method via navigation*.

3.4 Teaching and Activities

Teaching and activities, as a special teaching and learning theory unit, describes the following major issues: the role of feedback in the teaching and learning process, and teaching and learning for desired degree of activities.

While successful learning of new material does not necessarily depends on feedback (for example, problem demonstration does not involve efficiency analysis), feedback often appears as a key point in the learning process. Feedback control from the problem to the learner transforms mere problem solving to problem-oriented teaching. Both constructivist philosophy and activity-orientedness learning involve feedback. The role of feedback in the learning process can be ranged as follows:

a) Total lack of feedback, excluding learning (case of trying to hit an unseen target to with a stone);
b) Internal feedback enabling the learner's independent judgment of (in) efficiency (case of hitting a visible target with a stone);
c) Simple evaluation feedback from others present (case of response to a funny story);
d) Diagnostics, or descriptive feedback, describing both effective or ineffective learning, and required modification and, possibly, reasons.

Accumulating more knowledge, the learner is less dependent on external feedback, referring more functions to internal feedback and acting more freely. However, as internal feedback sufficiency cannot be guaranteed, *constructivist strategy necessarily involves diagnostic feedback* as an essential learning component. Most members of academic communities believe in book learning, with subjects like distant stars or past civilizations in astronomy or history respectively, defying any action. On the other hand, multiple evidence exists for the opinion that learning is impossible without acting on the subject. The phrase "I act and I understand" occurring in the literature on teaching and learning (Laurillard, 1993) reflects an extreme view of the role of activities in learning. A rational view of desired degree of activity in the learning process can be formulated as follows. While activity-orientedness approach to the subject of study is important in any case, the influence degree and final learning achievement depend on the following:

a) Non-active learning is only effective with the student possessing a well-adapted model for new information. The newer the material to be learned, the more important the feedback and activity-orientedness approach.
b) The need to obtain information via external feedback (necessitating activity-orientedness approaches) is often important with internal feedback undeveloped or a part of the solution completely lost (forgotten) and the student unable to proceed without external assistance.
c) Acting on the subject of study/learning can be regarded as a testing component in the learning process.

4. RESULTS AND DISCUSSION

There are many pedagogical and psychological approaches and methods, which are not applied to any of components of the architecture of ITS, especially the tutor model. The most important of them are:

(a) The concept of "teaching episode" and transmission of knowledge from the tutor to the student is a necessary result of the philosophy of structuralism. Constructivist approach states the concept of "teaching episode" and transmissions of knowledge to be only a co-reason of learning and that it works only in case when external environment is the determining factor. The second cause is learner's activity, governed by previous learner's mental experience.

(b) Teaching could not be based on divided process of receiving of declarative knowledge and procedural knowledge. Declarative knowledge represents generalizing of procedural ones, and receiving of the first should be based on active experience or procedural knowledge. Thus, effective teaching presumes alternate acquiring of procedural and declarative knowledge.

(c) Motivation is an important psychological factor of learning and its influence grows with years. Motivation can be interpreted as learner's readiness for mental effort. Thus, motivation allows offsetting expected nuisance of required mental effort in learning new material.

(d) The problem of next step or navigation is innate to learning process. The approach based on that concept of transmission of knowledge presumes that navigation depends on tutor, whereas constructivist approach considers mental experience of learner has an internal navigation method.

(e) More knowledge collected - less need for external feedback and more functions of internal feedback so learning behavior become more independent.

5. CONCLUSION

In this paper, we tried to review the teaching and learning theories, attempting to describe their relationships, for improving the tutor model of ITS. The tutor model of ITS is composed of a set of teaching strategies that determines, which teaching action to be deployed according to the current cognitive state of the student. Teaching strategies implemented in ITS are not based on the old and recent developments in pedagogical science and pay no attention to both general principles of teaching and learning theory and many classical teaching methods suggested by practicing teachers. However, teaching and learning theories must be utilized in teaching strategies designed in the tutor model of ITS.

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