Student Models: The transit to Distance Education

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Abstract

This study is an effort to explore how the Student Models can be useful in distance education. The study can be virtually divited in two parts. The first part concerns the use and achievements of Student Models in Education while the second part reports Student Models that may apply in asynchronous distance education in addition with some criteria for testing the applicability of such models.

Keywords: Student Models, Student Modelling, distance education, Asynchronous distance education.

Introduction: Uses and achievements of Student Models in Education

Student modeling is defined as the task of describing the knowledge and beliefs of the student as a basis for the decision on appropriate actions for feedback. According Barr and Greer: "Student Model represents student understanding of the material to be taught with the purpose to make hypotheses about students' misconceptions and suboptimal performance strategies" (Barr et al., 1982).

The subject of how students learn and acquire knowledge gained major interest by the teachers in conventional education. Over the years teachers have changed their strategies because the knowledge of how students learn increased. These strategies were subject to change as teachers kept on learning about students. Development of Artificial Intelligence provided new horizons for the evolution of Student Models. Student Models had been extensively used in the development of:

- Intelligent Learning Environments,
- Intelligent Tutoring Systems,
- Intelligent Computer Aided Instruction Systems,
- Multimedia Educational Environments
- and lately of Web based Instruction Systems.

Extensive use of Student Models derived from a number of different reasons. One of the basic intentions was to monitor and understand student reasoning and misconceptions, a quite difficult task, since student reasoning was not directly observable. The identification of ways to adapt and guide teaching on an individual basis according to the student's cognitive characteristics and learning behavior was a different approach. Yet another reason was the purpose of performance assessment and certification of a student's mastery on a given context.

Several different uses of Student Models had been reported in the literature (VanLehn, 1988; Nwana, 1991; Holt et al. 1994). Ragnemalm (1999) identified that the uses of Student Models can be divided in four categories:

a. Planning education: What topics are to be learned? Which are well known?
b. Planning delivery: What experiences are suitable to encourage learning of the intended topic and which previous experiences can be utilized?
c. Generating feedback: Feedback on performance should build on previous knowledge as well as current conditions.
d. Remediating misconceptions: Remediating misconceptions can be done by pointing them out to the student, either by providing counter evidence or by heaving a meta-level discussion. (p. 17)

Yet another aspect that motivated the use of Student Models was the recording of students' learning styles (by examining their learning speed) and their motivation to learn (by encouraging collaboration or competition with peer students).

The general achievements gained by the use of Student Models in education were the inspection and analysis of students' mental behavior, of their reasoning and of the knowledge that was believed to underlie such behavior. In the following list some particular achievements are reported as they appeared in the literature resulting from the use of Student Models:

- Elicitation of students' misconceptions from observed errors during a problem solving process (Matsuda and Okamoto, 1992).
- Diagnosis of students' behavior in a procedural problem solving session (Matsuda and Okamoto, 1994)
- Assessment of students' expertise on a given domain (VanLehn and Martin,1997, p. 179-221; Conati and VanLehn, 1996; Katz and Lesgold, 1992, p. 205-230).
- Construction of bug libraries based on students' misconceptions (Greer and McCalla, 1994, p. 8; Baffes and Mooney , 1996).
- Long-term knowledge assessment, plan recognition and prediction of students' actions during

problem solving (Conati et al., 1997, p. 231-242).
- Inference of students' problem solving ability, acquisition of new topics and retention of earlier topics (Beck, Park and Woolf, 1997, p. 277-288).
- Representation of the granularity of knowledge (Collins et al.,1996).
- Improvement of students' performance by provoking either student-teacher interaction or interaction with a peer student (Bull, 1997; Bull and Brna, 1999).
- Support of students' writing skills (Bull and Shurville, 1999)
- Assessment of students' self-explanations (Conati and VanLehn, 1999).

Typical examples of Student Models

A number of Student Models have been reported in the literature. Some of the implemented models were domain independent while some others had domain dependency.

Domain independent Student Models

Greer and McCalla (1994), in their book"Student Modelling: The Key to Individualized Knowledge-Based Instruction," report a number of domain independent Student Models introduced by Kass (Kass, 1989, p. 386-410).

- Overlay Student Model: According to this model the learner's knowledge at any point is considered as a subset of an expert's knowledge.(Greer and McCalla, 1994, p. 7)
- Differential Student Model: According to the Differential Student Model the learner's knowledge is divided into two categories: knowledge that the learner must know and knowledge that the learner can not be expected to know.
- Perturbation Model and Bug Library: While the overlay model represented the learner only in terms of "correct" knowledge, a perturbation model normally combines the standard overlay model with a representation of faulty knowledge (Greer and McCalla, 1994, p. 8).
- Constraint-based Student Model: A constraint-based Student Model represents the learner knowledge as the constraints upon the correct knowledge representation.
- PairSM Student Model: PairSM is a domain-independent system introduced by Bull and Smith, aimed at helping pairs of students to organise their revision for an approaching test (Bull and Smith, 1997, p. 339-341). PairSM contains two individual Student Models that are compared by the system to enable it to suggest ways in which two students may work together effectively. The aim is to encourage students to experience the benefits of peer interaction.
- PeerISM Student Model: PeerISM is another domain-independent system introduced by Bull and Brna. PeerISM is an inspectable Student Model aimed to promote effective peer interaction enabling the students to build their own model of a domain which may be improved through reciprocal student modeling with a peer student and subsequent face-to face peer negotiation of a domain model (Bull & Brna, 1999).

Student Models with domain dependency

See Yourself-Write Student Mode: The See Yourself-Write is inspectable Student Model introduced by Bull, to promote learner reflection and to encourage learners to use the feedback received from their tutors in their future assignments. (Bull, 1997, p. 315-326) The domain to which this model was applied was writing in a foreign language.

How can Student Models be useful in distance education?

The development of new technologies has promoted an astounding growth in distance education, both in the number of students enrolling and in the number of universities adding education at a distance to their curriculum.
Teaching and learning at a distance requires special attention to the possibilities and limitations of the technologies involved. Even many simple activities, which are taken for granted as part of the instructional process, have to be reconsidered and adapted to new circumstances. Pedagogy of distance education has to be broken into issues that concern the instructor, and issues that concern the student. The area of distance education can be positively affected by the use of Student Models promoting the achievement of better teaching and learning activities.

Student models can be used in asynchronous distance education in a similar way to the one that has already been used in traditional education. As it was earlier reported Student Models are used to elicit information from the students regarding their misconceptions or their weaknesses during the learning session, or regarding their learning pace. Furthermore, Student Models are used to provide help and feedback to the students according to their learning preferences. Such beneficial use of Student Models can also be valid in asynchronous distance education. However, a critical difference appears when comparing the use of Student Models in asynchronous distance education to the ones used in traditional education. In the latter case Student Models are used as one of the central components of Intelligent Tutoring Systems or of Multimedia Educational Environments. The main scope in traditional education is the achievement of an improved simulation of a virtual tutor or of a peer student so that more effective educational sessions are achieved when students interact with the system. So the central idea is the improvement of individualised learning as the system, guided by the Student Model component, tries to perform the best adaptation to the learning preferences of each individual student. Thus, Student Models are considered as the backup support component of the computer based educational systems in order to meet the students' learning needs. In most cases Student Models are not observable by the students and they are used for internal computational implementations.
The above situation is differentiated when confronted with an asynchronous distance education session. Although the main idea of supporting students' learning needs remain valid, the use of Student Models has a totally different orientation. The key concept in this case is not the improvement of the adoption of some computer-based educational environment but how to help both the students and the teacher to achieve more effective educational sessions.

The learning material in asynchronous distance education can be accessed or read by the students at any time. Similarly, questions can be asked asynchronously to other classmates as even the study pace can also be different. This discontinuity of the education session in addition to the lack of face to face contact causes a pedagogical disadvantage affecting both the tutor and the students.

Tutors may become confused or incapable of monitoring the individual learning needs or the misconceptions of the distance students. Tutors may also have problems locating a particular e-mail among the others in their in-boxes, which address a study problem of a student. The problem may be the inability of the tutors to keep a track of the feedback provided to each student, especially when a large group of students is supervised.

Students on their side may felt isolated being at "a real distance" from their tutor and their classmates. Lack of intense supervision related to students' individual learning needs may also be recognized in addition to the lack of effective support or guidance on how to overcome a misconception or remedy a performance gap.

Thus Student Models used in asynchronous distance education may act as an intermediate communication component between the tutor and the students, recording the tutor's suggestions and feedback regarding the students' progress, in addition to the comments made by the students regarding their personal problems or the misconceptions which occurred.

Criteria testing the applicability of Student Models in distance education

The criteria of testing the applicability of Student Models in asynchronous distance education can be categorized as follows:

- Generic criteria, which concern the general features of a Student Model such as implementation issues, domain dependency etc.
- Specific criteria, which concern specific pedagogical issues that the Student Model should support such as the promotion of collaboration, improvement of context comprehension, etc.

In more detail the generic criteria used to examine the applicability of the Student Models are:

- They should accurately explain student behaviour independently of the domain tackled. Due to the variety of the educational subjects provided via distance education, the Student Models should be able to capture and explain the students' behaviour regardless of the context of the taught course. This assumption, though, does not imply that the entire domain of dependent Student Models that have been developed are inapplicable in the area of distance education. However, reviewing domain dependent Student Models towards each educational subject available via distance education would be impractical.
- They should be easy to handle and to maintain. For practical reasons Student Models should be easy to handle and to maintain by the instructor. In the case of distance education the problem does not focus only on just collecting some statistical data for computational use regarding the students' progress. On the contrary, such models should assist the instructors to understand and easily monitor the students' performance on a continuous basis and during the educational session.
- They should be inspectable by the student and available for consulting on request by a student. The context of a Student Model should not be used only for computational implementations kept hidden from the students. On the contrary, the context should be kept in a format meaningful, and easy to use by the student, continuously accessible whenever the student requests it.

The specific criteria met by a Student Model applicable in an asynchronous distance education are:

- Should be beneficial to both the tutor and the student. In conjunction with the third generic criterion, the need for simplicity and ease of understanding in Student Models derives from the fact that distance education is addressed to students who vary greatly in their educational background. The majority of the student population is not aware of or familiar with the use of complicated software products. Due to the lack of physical tutor-student contact, sometimes the distance student has the feeling that the teacher is unreachable when needed. This is the reason why Student Models should provide bi-directional benefit to both instructors and students, by enabling students to monitor their own progress and utilise the feedback signals propagated by the model on a continuous basis. In that way Student Models can be simulated to an off-line student support system by remedying student performance problems and by reporting their progress whenever the student accesses them.
- Should contribute to the improvement of context comprehension by highlighting students' misconceptions or students' poor performance on a given topic and, further, recording interactions between the students and the teacher, or the students' peer tutoring sessions.
- Should promote student self-reflection and self-explanation, not only by reporting the students' misconceptions but also the reasons that they occurred.
- Should facilitate students' supervision by enabling the tutor to have a solid and continuous view of the students' performance, including both quantitative and qualitative information, apropos the students' individual weaknesses and strengths.

Report of Student Models that may apply in distance education

The models evaluation has been carried out according to the above mentioned criteria and has been separated in two sections for each model, the Generic section (G) and the Specific section (S).

(G) The Overlay Student Model is domain independent and has an easy representation of both knowledge spaces (tutor's and student's). A clear final target can be identified which is to increase the student's knowledge space as much as it is possible so that the differences between the two knowledge spaces is minimised. This model may employ objective methods in the creation of learning instructions as it expects a minimum of prior knowledge and skills on the student's part towards the taught domain. Objective methods provide a series of steps that lead the learner to the final goal (behavior that the student should have by the end of the instructional session; i.e. the student should be able to save documents on a floppy disk).
There is no information available as to whether such a model is inspectable by the student nor on how it is updated as the learners' knowledge increases. Thus, no conclusion can be drawn on the ease of handling and maintenance of the model or its inspectability.

(S) The Overlay model can be beneficial for both the student and the teacher, and facilitates student

supervision as the model represents the growth of the students' learning space.
On the other hand, the model does not provide facilities to promote students' self-reflection nor any kind of indications of improvement on context comprehension

(G) The Differential and the Perturbation Student Models assume that all gaps in the Student Model are not equally undesirable, nor that the student's knowledge is considered as a mere subset of the expert (tutor). For example, a distance student may not be able to indicate the characteristics of the self-paced corresponding studies but to be able to develop effective and well designed web pages, while the instructor can not. Such differences in the student's and in the tutor's knowledge space are not undesirable, neither can they rank the student as a novice. On the contrary, the learner is assumed to possess knowledge potentially different in quantity and in quality from the expert knowledge.
These models similar to the Overlay Student Model are domain independent, and they represent both student knowledge and student-expert differences more explicitly. Furthermore, similarly to the Overlay model no information exists on the inspectability or the maintenance of the two models.
Both the Differential and the Perturbation models may employ constructivistic methods in the creation of learning instructions, allowing the student to take control of the learning.

(S) The two models satisfy all the specific criteria with special reference to the Perturbation model, where the utilisation of the bug library provides information promoting the students' self-reflection and hints on context comprehension.

(G) Similar analysis to the Overlay model applies to the Constraint Based Model, though some variation points exist.
According to the first generic criterion this model can only be applied on deterministic domains, while referring to the second criterion the model seems easy to maintain since no computational complexity exists within the model (once constraints are violated, update of the model is required).

(S) Another variation on the specific criteria is the fact that the model promotes the students' self-reflection, as the student is represented as the constraint upon the correct knowledge representation.

(G) PairSM is also a domain independent model that has exceptional interest as it can be used to monitor collaborative learning, critical issues in distance education.
This model has clear representation of the students' knowledge space as a team and as individuals. The model is also updated on a continuous basis by the subsequent tests entered by the tutor.
Although the model is easy to maintain, no information exists on the inspectability of the constructed Student Models by the students themselves.

(S) In pairSM once the students have individually completed the tests, the system is able to consider where help is needed most, and whether the students can usefully collaborate with or tutor each other. Students can later return to PairSM to take another test. The system is then able to compare the results of the collaboratively taken test with the identical, but individually taken version, before making its next recommendations (Bull and Smith 1997, p. 339-341).
In conclusion, this model satisfies all the specific criteria as the collaborative learning contributes to the context comprehension and to the student' self-reflection and explanation. Furthermore, the tutor via the system is able to monitor the students' progress, both as a group and as individuals.

(G) PeerISM can be considered as one of the most appropriate models to be applied in an asynchronous distance education session. The model being domain independent seems an attractive solution for distance education, since it is easy to maintain and handle as it is based on the analysis of students' textual interactions.
The constructed models are inspectable on both sides, the tutors' and the students'. The models can also be modified after a number of interactions among the students.

(S) The model also satisfies all the specific criteria. In more detail, collaboration interaction about students' knowledge aims to enhance understanding of the domain and to raise awareness of the learning process.

Self-assessment and colleague evaluation facilitate the self-reflection and explanation to a great extent. Furthermore, the model acts beneficially on students' supervision as both quantitative and qualitative information is stored in the model.
The only problem seems to exist in cases where both students share the same misconception. In such case there is no information available on how the system will identify the problem since the system's indication of misconceptions occurs only when incompatibility on a student's self- evaluation is detected.

(G) Finally the See Yourself-Write Student Model is implemented to improve writing skills in a foreign language. It could be used as a domain independent Student Model aiming to improve student's performance by utilising tutor's feedback. This model is considered to be the most appropriate model to be applied in asynchronous distance education as it successfully meets all the generic and specific evaluation criteria.
The model is easy to handle and to maintain on the teacher's side as the latter could enter his/her comments and view the results in plain text without complicated computational procedures. The tutor's additional comments are also available to the student's eyes and the student can also argue on these comments by entering his/her point of view, or keeping notes regarding the reasons that have caused a potential faulty performance. In this way a bi-directional interaction between the student and the teacher is achieved, while the Student Model acts as an intermediary system.

(S) The above feature also affects the specific criteria especially the improvement of context comprehension in addition to the promotion of the student's self-reflection and explanation.
In most of the courses available via distance the tutor provides feedback to the students through the assignments, trying to help them to improve their performance or to highlight their weak points.
This model utilises to a maximum level this process of feedback provision. The system not only keeps both quantitative and qualitative comments for each particular assignment but it also automatically constructs and updates an individual Student Model based on the feedback provided each time by the teacher via the corrected assignments.

As Susan Bull indicates See Yourself-Write model is aimed at helping learners to reflect on their performance, and to think about how they might improve their work by:

- viewing and interacting with a student model based on teacher feedback;
- making it easy for students to access useful comments on earlier work when composing a new piece of work;
- being prompted to explain how they could improve, or to give reasons to explain their improvement/deterioration, etc.;
- being encouraged to take advantage of self-explanation of difficulties by disguising this as a request

for outside assistance.

Additionally, the facility for students to disagree with the model also enables teachers to become aware of their mis-diagnoses (Bull, 1997, p. 315-326). As a final remark, the See Yourself- Write Student Model has a different aim from that of more conventional learner models; "... it was not intended as a source of information for a computational educational system, but rather as a source of information for the student." This is one of the central strength points of the See Yourself-Write Student Model.

Summary

In the present study the issue of the applicability of some of the developed Student Models on the area of distance education was examined. It has to be mentioned that a new role was assigned to the use of Student Models in asynchronous distance education. Models in this case act as an intermediate communication component between the tutor and the students, recording the tutor's suggestions and feedback regarding the students' progress in addition to the comments made by the students regarding their personal problems or the misconceptions which occurred.

In order to evaluate the applicability of the reviewed Student Models, both generic criteria (concerning general features of the models such as domain dependency) and specific criteria (concerning pedagogical issues) have been used.

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