S. L. Wong et al. (Eds.) (2010). Proceedings of the 18th International Conference on Computers in Education. Putrajaya, Malaysia: Asia-Pacific Society for Computers in Education.

Evaluating the Effectiveness of Multiple Open Student Models in EER-Tutor

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Abstract: Open Student Models (OSM) are beneficial for improving students' domain knowledge and meta-cognitive skills. The way in which the student model is displayed may be an important factor which has not been investigated adequately in the context of Intelligent Tutoring Systems (ITS). In our study, the control group had skill meters, while the experimental group additionally could access the OSM represented as a concept list, concept hierarchy or a concept map. The results show that OSM do have a positive effect on students' learning. However, the students showed clear preferences towards simpler representations than the more complex ones.

Keywords: open student models, constraint-based tutors

Introduction

Student models provide the basis for adaptive instruction, but students are very often not aware of their existence. By opening the student model, the system becomes more user-friendly. More importantly, the OSM serves as a learning tool on its own; by showing the system's understanding of the student's knowledge, the student is encouraged to reflect on his/her knowledge. Students are capable of scrutinising their models [4], and are able to understand and control the adaptation. OSMs engage students in thinking about their own knowledge, thus involving the student at the meta-cognitive level. Studies show that OSMs raise students' awareness of their knowledge and encourage reflection [2, 3, 7, 10, 11].

OSMs have been used in a variety of systems, ranging from the text editors [5] to ITSs [1, 11]. In some cases, developing the open student model is the primary activity the student is involved with (e.g. [6]). The actual representations used for OSM range from simple skill meters, represented as progress bars indicating the percentage of material a student has learned for a particular topic or concept [1, 2, 11], to more complex representations. A concept/topic hierarchy is a tree structure built on the basis of conceptual relationships in a domain [5, 9, 10]. Concept maps have also been used for OSM [6, 13], but they are more complicated and may be difficult to design and understand [9].

Any visualization chosen for the OSM has pros and cons, and might be preferable in terms of domains, system types, educational goals, and students' knowledge levels. Therefore the use of *multiple* visualizations for the OSM may be more preferable for both educators and learners [8]. Recently, Mabbott and Bull [10] investigated the effect of multiple presentations of the OSM, and note that students show appreciation of OSM and do have preferences for a particular presentation. However, their study was done in a context of a simple educational system, where students answered multiple choice questions. Our study focused on the effect of multiple OSMs in an ITS, where the primary student activity is problem solving. We compared skill meters, a simple representation of the student model, to three other representations: concept list, concept hierarchy and concept map. The study was done in the context of EER-Tutor, a constraint-based tutor that teaches conceptual database design [14, 15]. Domain knowledge is represented in terms of constraints [12], and the student model shows how much the student has learned. The OSM is shown on request, in the form of eight skill meters representing the student's progress on the major components of the EER model. The length of a bar indicates the relative amount of knowledge (in terms of constraints) for that particular component. The bar is divided into three distinct sections. The first (green) section represents correct knowledge (i.e. the percentage of relevant constraints that the student used correctly). The second (red) section gives the measurement of misconceptions, by presenting the percentage of relevant constraints that the student has not learnt, and the last (white) section shows the percentage of relevant constraints the student has not used at all. In addition to the skill meters, the OSM also presents two numerical indicators for each component, one for covered knowledge, and the other for correctly learned knowledge. We define *covered* as the fraction of the constraints relevant for the particular component the student has used over all relevant constraints for that concept. *Learned* is calculated as the fraction of relevant constraints the student has used correctly over all relevant constraints.

1. The Study

Although skill meters are easy to understand, they do not provide details and need to be complemented by other views of the OSM. We designed three additional visualizations of the OSM: concept list, concept hierarchy and concept map. In all three of them, we show the covered and learnt percentages, calculated as specified in the previous section. The concept list represents the full list of domain concepts represented as skill meters. A concept hierarchy shows all the concepts, and additionally shows the relationships between concepts, thus providing more information about the domain structure.

Some relationships among EER concepts are intricate and require a map-like view to visualize them. We have designed an EER diagram to represent the concept map of EER domain. By examining this EER diagram, students have a chance to enhance their meta-cognitive skills, learn about the domain, and study an example of EER modelling.

We conducted a study in March 2009 at the University of Canterbury, with students taking an introductory database course. The control group was given access to the original EER-Tutor, which presented only skill meters. In contrast, the experimental group used the EER-Tutor with extended OSMs. We wanted to see whether students show any preferences over the new OSMs, and also whether elaborate OSMs affect student learning.

The students started with a pre-test, followed by problem solving. To promote the use of OSM, the student model was shown at the beginning of each session. The participants could access EER-Tutor for three weeks, and then post-test and a questionnaire were administered. Table 1 presents the results, which show that the groups had similar pre-existing knowledge, spent comparable times with the system, and viewed/requested the OSM similar number of times (*Viewings total/Viewings self*). The amount of time they spent viewing the OSM (*Viewing time*) is also similar.

Only 36 students completed the post-test. We analyzed the pre-test results for only those 36 students, and the t-test reveals no difference (*Pre-test - subset*). There is also no significant difference on the post-test. The performance of the control group did not increase significantly between pre- and post-test, but there was a significant improvement for the experimental group (p=0.04). The experimental group learned more than the control group. Using normalized gains, calculated as (post-test – pre-test)/(100 – pre-test), the effect size (Cohen's d) is 0.22. Although the effect size is small in the absolute value, it is still important, as the only difference between the two groups is the OSM provided and it still resulted in an improvement for the experimental group.

Table 1. Some statistics from the study (sd given in parentheses)

	Control (42)	Experimental (44)	p
Pre-test (%)	61 (24)	53 (25)	ns

Interaction time (min)	353 (304)	327 (253)	ns
Viewings total	18.6 (13.1)	15.3 (10.9)	ns
Viewings self	2.3 (2.4)	2.5 (3.7)	ns
Viewing time (min)	4.2 (7)	4.9 (8.5)	ns
# Post-test completed	19	17	
Pre-test - subset (%)	63 (24)	57 (18)	ns
Post-test mean (%)	69 (15)	68 (16)	ns

27% of the experimental group never requested to see the OSM, while that percentage for the control group is 23%. The experimental group participants spent more time on concept hierarchy, compared to concept list and concept map, although the differences are not significant. The average numbers of viewings were similar for the three presentation styles, but the concept map was the least popular.

The questionnaire replies show 72% of the control and 75% of the experimental group participants found OSM useful for their learning. Students were also asked whether the OSM correctly reflected their ability in solving EER problems. 53% of the control group thought the OSM was correct, compared to 80% of the experimental group; the difference is marginally significant (Fisher's exact test, p=0.1). Therefore, the more detailed OSM was more believable. The experimental group showed different preferences over the views we provided, with the majority favouring skill meters (53%) due to their simplicity, and no one preferring the concept map. These initial results are encouraging, and we plan to perform additional studies in the future.

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