Submitted to: The Encyclopedia of Distance Learning, Teaching, Technologies and Applications.
Idea Group, Inc.

Open Student Models: Mirror Modeler

Eshaa M. Alkhalifa
University of Bahrain

EVOLUTION OF OPEN STUDENT MODELS

When a student makes an error, the instructor wonders what possible misconception caused that error (Self, 1990) and attempts to correct it through altering the instruction method. Consequently, student models represent the system's assumptions of learner knowledge and preferences without giving any guarantees that this model accurately reflects any of the information it contains.

These models are utilized to present the right type of materials at the right point in time in the right presentation style (Fisher, 2001) in order to achieve optimal knowledge transfer. There are two main approaches followed when modeling student knowledge. The first, attempts to delve into the cognitive workings of the student's mind and tries to best explain how the results could be obtained. Some of those who followed this approach are: Martin and Vahn Lehn (1995), Langley, Wogulis and Ohlsson (1990), Ikeda, Kono and Mizoguchi (1993) amongst others. The second approach assumed that the process that occurs between the "inputs" and "outputs" that occur in a "black box" scenario. The researchers who adopt this presumption attempts to formulate a mapping between the situation and student response to that situation. Some of those who are following this type of modelling include Webb, Cumming, Richard and Yum (1991) and Webb and Kuzmycz (1996).

Those who follow the first approach are in a sense predicting possible causes for student behavior. In order to be able to check the accuracy of the student model in representing the student's cognitive characteristics, VahnLehn and Niu (2001) conducted a study in sensitivity analysis. They found out that an Intelligent Interface is more likely to result in erroneous assumptions about student knowledge than a Computer Aided Instruction Interface. They also found out that the accuracy of the model is strongly dependent on the inputs given to the modeler.

The fallibility of these modelers opened up a new avenue of research where students are allowed to see and learn from their models. This in short is an Open Student Model. Dimitrova, Self, and Brna (2000) indicate that when a student is allowed to join a discussion about his learner model then he is engaged in the process of reflecting upon his knowledge and reconsidering the ideas and assumptions he has formed.

Misconceptions are consequently discovered by the learner and corrected. Existing approaches for involving the learner in the modeling process include open learner models (Paiva & Self, 1995), collaborative student models (Bull, Brna, & Pain, 1995) and interactive diagnosis (Dimitrova et al.,2000). These are listed in Table 1 along with their main features.

Table 1.
Classification of existing types of open student modelers

Classification of Model	**Dynamic Learner Modeling**	**Collaborative Student Model**	**Interactive Diagnosis**
Example Modeler	Tagus (Paiva and Self, 1995)	Mr Collins (Bull et al. (1995)	STYLE-OLM (Dimitova et al. (2000)
Communication Approach	Students can alter the model by typing prolog clauses or altering options	A student can “negotiate” with the system concerning the model through a special interface by selecting options from a menu.	Communication is organized as an exchange of speech acts where dialogue moves are extracted from a framework for analyzing education dialogues.
Level of Student Involvement	A student can alter the model	A student can negotiate with the system and have a different view than the system.	A student can only see the model and question it but not alter it.
Method of presentation	Not very user friendly because the model is a series of prolog clauses.	The model is shown as tables which contain domain rules so it is not very user friendly.	It has a graphical interface of the learner’s belief network.

Allowing students to alter their own models may prove counter-productive to the learning process, while displaying the models in the three given forms also proved to lack user friendliness as students required details instructions teaching them how to interpret the first two of the system. The third was not evaluated.

The aim of having an open learner model is clearly to allow learners to reflect on their errors and consequently the model should be presented in a form that would help achieve that goal.

MIRROR MODELER

The mirror modeler represents a novel open modeling approach where students are shown a list of the errors they are most likely to make in English. On the same page a student can instruct the system to mimic how he would solve several sample problems with those errors and compare that to how the ideal solutions are generated.

What differs here from all of the above modelers is that subjects are able to see their solution path from an external point of view as the system generates their errors. Students do not need any prior knowledge to aid them in comprehending the model, nor are they capable of altering the model so it resolves some of the issues that arose with the other types of modelers. This approach was evaluated through several experiments at the University of Bahrain (Alkhalifa, 2004; Alkhalifa & AlDallal, 2002).

The mirror modeler was tested as a part of an Internet based interactive tutorial system set up to teach mathematical summations of the form:

$$\sum_{N=1}^{6} N = 1 + 2 + 3 + 4 + 5 + 6$$

Teaching can be in two directions; either giving students the Summation Notation and asking them to expand it giving the numbers on the right, or giving them the numbers on the right and asking them to return the Summation Notation. The second task is of course, much more challenging than the first. The system is composed of a tutorial section, a practice test section, test section, and a model comparison section.

The tutorial section is composed of two main parts; the first teaches them how to generate the series from the summation notation while the second teaches them how to generate the notation from the series. The practice test section allows students to insert the notation they believe to be the answers and are shown the series generated from their inputs.

The test section examines their comprehension of the lessons given and student responses are utilized by a rule based expert system to diagnose the types of errors made. The errors are then listed in English to the student along with the probability of making that error represented as a percentage. Students can also observe the system while it generates the solutions that students are likely to give in response to different problems from the above while it is guided by the probabilities.

Results of the tests are represented in terms of the total number of errors made according to the summation operation type is shown in Table 2. The summations shown are only examples of one of the two used as numbers were altered as well as the order of the questions in order to prevent students from remembering the pretest questions when performing the post test questions.

Table 2
Number of errors made by students classified according to summation operation type. Additionally, the percentage of correct responses is given in brackets.

	No of Students	Type of Test	Division $\sum_{i=1}^{10} i/4$	Multiplication $\sum_{i=2}^{11} 3i$	Power $\sum_{i=1}^{10} 2^i$
Interactive Tutorial	**21**	**Pre**	**56 (55.6%)**	**70 (44.4%)**	**54 (57.1%)**

Interactive Tutorial	21	Post	14 (88.9%)	25 (80.2%)	28 (77.8%)
Tutorial + Mirror Modeler	**12**	**Pre**	**6 (92%)**	**21 (70.8%)**	**10 (86.1%)**
Tutorial + Mirror Modeler	12	Post	0 (100%)	1 (99%)	17 (76.4%)

The effect of having the modeler as part of the system has brought the marks in both the Division and Multiplication type problems close to 100%. By converse, the mirror modeler exhibited a damaging effect with respect to the more complex Power operation while the interactive tutorial maintained its ability to teach that form of series.

CONCLUSION

One should consider the role of student modelers in learning, not just as the drivers of Intelligent Tutoring Systems but instead as a learning medium in their own right. Brockmeier (1996) defines the central claim of “child’s theory of mind” that children learn how to understand human activity by attributing mental states to the actors. In this view, a child is regarded as someone who constructs mental models of their social world in order to utilize this model for learning.

The mirror modeler therefore, offers students the ability to regard their own actions from an “external” point of view in order to judge their approach to solving the problem, which according to the above theory should be facilitators to learning. It therefore raises the cognitive level at which they learn from that of Application where they learn how to apply what they learnt as defined by Bloom (1956), to the level of Analysis where they would analyze the solution path as the system mimics them.

Results indicate that this raises the complexity of the thought patterns required in the learning process and while this proved to be a facilitator to learning of certain functions, it is a hindrance to higher order learning as is exhibited by the “power function series” problem.

A clear result that one may make from this is that the cognitive capacity while learning is limited. This supports the claim made and supporting results in (AlBalooshi & Alkhalifa, 2002) that utilizes the concept of “Cognitive Tools” (van Jooligan, 1999) to relieve the cognitive load of learning to facilitate learning of processes. At the same time, mirror modelers raise the cognitive level of learning for some topics resulting in much higher levels of transfer for operations that do not require higher order thinking.

REFERENCES

AlBalooshi, F. & Alkhalifa, E. M. (2002), Multi-modality as a cognitive tool, Special Issues: Innovations in Learning Technology, T. Okamoto & R. Hartley

(Eds). *Journal of International Forum of Educational Technology and Society, IEEE*, *5*(4), 49-55

Alkhalifa, E. M. (2004), The effects of live problem solving in an internet based mathematics tutorial system. *Proceedings of the 2004 Information Resources Management Association International Conference, IRMA 2004, New Orleans, Louisiana, pp. 868-870*.

Alkhalifa, E. M. & AlDallal, L. (2002), Mirror Modeler: A web based interactive mathematics modeling system. *Proceedings of the International Conference on Computers in Education, ICCE 2002, Auckland, New Zealand*

Brockmeier, J. (1996). Construction and interpretation: Exploring a joint perspective on Piaget and Vygotsky, In A. Tryphon and J. Voneche (Eds.) Piaget – Vygotsky: The Social Genesis of Thought (pp. 125-143). Psychology Press, UK.

Bull, S. Brna, P. & Pain, H. (1995), Extending the Scope of Student Models, User Modeling and User Adapted Interaction, 5(1), 45-65.

Dimitrova, V., Self, J.A. & Brna, P. (2000). Involving the Learner in Diagnosis – Potentials and Problems, tutorial presented at Web Information Technologies : Research, Education and Commerce, Montpellier, France, 2-5 May.

Fischer G. (2001), User Modeling in Human – Computer Interaction, User Modeling and User-Adapted Interaction, 11, 65-86.

Ikeda, M., Kono, Y., & Mizoguchi, R. (1993). Nonmonotonic Model Inference: A Formalization of Student Modeling. Proceedings of the Thirteenth International Joint Conference on Artificial Intelligence: IJCAI'93,. Chambery, France, 467-473.

Langley, P., Wogulis, J. & Ohlsson, S. (1990). Rules and principles in cognitive diagnosis. In N. Fredriksen, R. Glaser, A. Lesgold, & M. G. Shafto, Diagnostic Monitoring of Skill and Knowledge Acquisition, (pp. 217-250), Hillsdale, NJ: Lawrence Erlbaum.

Martin, J. & VanLehn, K. (1995) Student assessment using Bayesian nets, International Journal of Human-Computer Studied, 42, 575-591.

Paiva, A., & Self, J.A. (1995), TAGUS – A User and Learner modeling workbench, User Modeling and User-Adapted Interaction, 4, 197-226.

Self, J. (1990), Bypassing the Intractable Problem of Student Modelling, in C. Frasson & G. Gauthier (eds.), Intelligent Tutoring Systems: at the Crossroads of Artificial Intelligence and Education, (pp 107-123). Norwood, N.J:Ablex.

Van Jooligan, W. R., (1999) Cognitive tools for discovery learning, International Journal for Artificial Intelligence in Education, 10, 385-397.

Vanlehn, K. & Niu, Zhendong (2001), Baysian Student Modeling, User Interfaces and Feedback: A Sensitivity Analysis, International Journal of Artificial Intelligence in Education, 12.

Web, G. I. Kuzmycz, M. (1996). Feature Based Modelling: A methodology for producing coherent, consistent, dynamically changing models of agents' competencies. User Modeling and User Assistant Interaction, 5(2), 117-150.

Web, G. I., Cumming, G., Richards, T.J. & Yum, K.-K., (1991), Educational Evaluation of Feature Based Modelling in a Problem Solving Domain. In R. Lewis & S. Otsuki, Advanced Research on Computers in Education, (pp. 101-108). Amsterdam, North-Holland.

Terms and Definitions

Cognition: The psychological result of perception, learning and reasoning.

Cognitive Level: The level of cognitive functions in the order of increasing complexity of cognitive processing.

Cognitive Load: The degree of cognitive processes required to accomplish a specific task.

Cognitive Tool: A tool that reduces the cognitive load required by a specific task.

Computer Aided Instruction Interface: A point of communication between a human a computer that is utilized with a system that is programmed to teach learners using a computer program.

Intelligent Interface: A point of communication between a human a computer that displays qualities that mimic traits observed in human communication such as the use of natural languages.

Mental Model: A mental recreation of the states of the world reproduced cognitively in order to offer itself as a basis for reasoning

Student Model: Different types of information that is obtained and retained by a computer program or module of an education system that includes information about achievement, learning level, preferences, etc.