Research Methods Tutoring in the Classroom

Peter WIEMER-HASTINGS
Jesse EFRON
School of Computer Science,
Telecommunications, and Information Systems
DePaul University
243 S. Wabash
Chicago, IL 60604

David ALLBRITTON
Elizabeth ARNOTT
Department of Psychology
DePaul University
2219 North Kenmore Avenue
Chicago, IL 60614-3504

Abstract. AutoTutor is very different from previous intelligent tutoring systems. It interacts with students using free-form natural language dialog as human tutors do. It uses approximate natural language understanding techniques to compare student answers to a set of expected responses. Evaluations of AutoTutor have shown that it can be effective in increasing student learning for multiple domains. In this paper, we present RMT (Research Methods Tutor) which is a direct descendant of AutoTutor. Research methods is a richer conceptual domain than some of the others in which AutoTutor has been used. We describe the types of topics which RMT will use, the differences in pedagogical strategies which it will include, and how it will be integrated into a research methods course at DePaul University.

1 Introduction

The AutoTutor system created a paradigm shift in intelligent tutoring systems. Unlike other dialog-based ITSs which put strong restrictions on how students can respond (for example [3, 7]), AutoTutor is meant to interact with students in the way that human tutors do: via natural language dialog [14, 5]. The system's dialog moves and knowledge representation are based on analyses of human tutors [10]. Despite the fact that the system has a very shallow student model, AutoTutor has been shown to produce significant learning gains for students by cooperating with them in the construction of a dialog about the tutoring topic [4].

RMT (Research Methods Tutor) is a descendant of AutoTutor [9] and is currently being readied for full-scale deployment in an undergraduate Research Methods in Psychology class at DePaul University. It uses the same general approach as AutoTutor and the same types of dialog moves. It extends those moves to different pedagogical strategies which are possible within the research methods domain. Furthermore, it takes a different pedagogical approach than AutoTutor. AutoTutor was designed to interact with a student in the same way that a tutor would. RMT will take the role of a research supervisor and the student will be a research assistant. The system will ask the students questions to assess their abilities, and will "assign" to the students tasks related to experimental designs, and will evaluate the results. This should provide a more realistic and motivating scenario for the students. This paper describes the topics that RMT will cover, the types of interactions that it will support with the students, and our plans for integrating it into the research methods course and evaluating its effects on student learning.

2 RMT's tutoring domain

We are currently developing tutorial materials which address several fundamental topics in research methods. These topics have been selected because they are critically important for the students' future success in experimental psychology, and because instructors have said that students would greatly benefit from a deeper understanding of them. The topics are:

1. ethics of psychological experiments: privacy, informed consent, ethics code, costs versus benefits;
2. types of studies: experiments and correlational (observational, archival, case studies, survey research);
3. variables: independent and dependent, operationalization, levels, causality, confounding, categorical and quantitative variables, scales;
4. reliability: systematic and random error, test-retest, internal consistency, factors that affect reliability; and
5. validity: types of validity (internal, construct, external, statistical), threats to validity.

In the next section, we describe how these topics lend themselves to tutoring in the AutoTutor style, and allow for an extension of the set of pedagogical strategies, including the different relationship to the student that RMT will assume.

3 Tutoring style

As previously mentioned, RMT's basic tutoring style is inherited from AutoTutor. AutoTutor's set of dialog moves was taken from analyses of human tutoring. AutoTutor presents information and broad questions (with or without supporting images), and accepts responses from the student. Each response is evaluated with various natural language processing techniques. Responses are classified as questions, short answers, frozen expressions, or replies with semantic content. For this last type of response, AutoTutor uses Latent Semantic Analysis (LSA [8, 14]) to compare the text of the response to a small number of expected answers. This differs from other recent systems like BEE [15], Atlas/Andes [11] and the Cognitive Geometry Tutor [13] which attempt to do full syntactic and semantic anaylsis of the responses. Depending on the type and quality of the response, AutoTutor then provides positive, neutral or negative feedback to evaluate student answers. To keep the dialog moving and suggest possible directions that the students' answers could take, the system uses hints, prompts, and elaborations. If the student provides a blatantly incorrect answer, the tutor can provide a splice to get the correct information "on the table". After a topic has been sufficiently covered, the tutor provides a summary of the complete answer, and moves on to the next topic. As evaluations of AutoTutor have demonstrated, tutoring with these dialog moves and an approximate understanding of student responses is sufficient to significantly increase student learning [14, 5, 4].

AutoTutor's Computer Literacy curriculum script includes some topics that discuss the basic facts of computers and computer use, and some more complex questions that require the student to make inferences about the implications of, for example, certain hardware configurations on the types of software that can be run. Again applying research on effective human tutoring strategies [6], the computer literacy topic includes a variety of example scenarios [5]. For example, one topic has the student discuss what they would infer about the effects of a virus on their computer.

In RMT, we continue to apply these same types of dialog moves for the tutor. But the richness of the domain allows us to expand upon this set in some interesting ways. The primary learning goal in research methods can be best considered as learning how to perform a process. Successful students will learn a variety of facts which form the foundation of the domain. This is no different from other domains. But research methods students must also learn what types of experimental methods to use in different situations and how to avoid pitfalls in applying them. Students have extra motivation to learn the techniques because they will not merely be tested on them, they will continue to use the methods as long as they stay in Psychology.

We are developing three types of tutoring topics that will help students learn these processes: factual/conceptual problems, analysis of example cases, and synthesis of their own designs for evaluating various example research questions. The first type of problem lays the foundation: these are facts that every student must know in order to be able to apply the processes. Analytical problems have the student critique an example experimental method, pointing out the benefits and flaws in each approach. Synthesis problems will require the students to design their own approaches to example research questions, building on their basic factual knowledge and knowledge about related examples. This type of problem is very valuable because the students see it as being an authentic task, and directed critiques from the tutor provide fertile and highly motivating conditions for learning [2].

The categorization of topics into conceptual, analysis and synthesis types naturally provides scaffolding for the students because of the progression of difficulty of the topics. It also allows for scaffolding within the topic types by providing progressively less information and demanding more from the student.

The modifications described above could be used within a typical tutor-student relationship. However, as mentioned above, it has been shown that a more authentic task setting will give the students additional motivation to learn the applicable concepts and processes (for example, [1, 12]). For this reason, RMT will assume a research supervisor/mentor relationship with the student. Although this is a fundamental change, many of the low-level behaviors that AutoTutor exhibits will remain unchanged. It is perfectly appropriate for a supervisor to assess the knowledge and abilities of a worker with conceptual questions. The analytic topics mentioned above can take the form of the supervisor asking the student to critique a design or to fix some (underspecified) flaws. The supervisor will assign the student to create a design for some situation “from scratch” to accomplish the synthetic tasks. The larger changes will be in the mechanisms for tracking student knowledge.

The first time that they use the system, RMT will tell them that they have been employed as a research assistant and will be paid a basic wage (in virtual dollars, of course!). Their salary will be based on their performance; understanding of more concepts and ability to complete more tasks will lead to higher pay. In order to track the students’ learning, RMT will use an expert model that describes the intended concepts, and a student model that is a subset of the expert model. RMT will choose topics at an appropriate level for the student (just beyond their current mastery) within a given session and throughout the term. As mentioned above, we will be developing topics in five fundamental areas of research methods, so the students will be able to use the system throughout a large portion of the course.

4 Implementation and integration into the classroom

The basic architecture of RMT is up and running. It provides web-based tutoring including a Microsoft-Agents-based talking head to present the tutor’s dialog moves to the students. Like AutoTutor, a transition diagram is used to describe the system’s process of choosing dialog moves to respond to the current state of the dialog. Unlike AutoTutor, RMT's dialog transition network is a fully functional element of the tutoring program. The tutor's dialog behavior can be changed by modifying the transition network. This will allow us to better monitor and experiment with the tutor's dialogs.

An internal grant from DePaul University is supporting the development and evaluation of the project. Before the system is evaluated in Winter, 2004, we will extend the current system in three ways. First, we will grow the system's corpus of research methods texts for training its LSA-based natural language understanding mechanism. We started with five chapters of text from a research methods textbook, and now have the text from two other textbooks and plans to acquire at least two more. The second focus is on developing new curriculum script materials. We currently have five topics defined to demonstrate the feasibility of our approach. We will need to create many more topics to cover the topics mentioned above with each of the three types of problems. Finally, we will need to extend the system to log interactions with the student and to track their progress through the topics. The details of our approach are given below.

To the best of our knowledge, AutoTutor has been used so far only as a proof-of-concept or evaluation system. A large number of tutoring topics have been developed in a variety of tutoring domains. The system has been shown to increase learning over normal classroom practice [4], but it has not been integrated for regular use in any courses. AutoTutor's student models are relatively shallow (mainly because of research that shows that human tutors don't have in-depth knowledge of their students' knowledge). It tracks which topics have been covered in a session and the overall quality of student contributions, but it has no need to keep track of students for multiple session.

In RMT we will extend the system's memory about students so that it can interact with the students effectively throughout the course. At least at first, we will log all of the details of the interactions with the students for the tutor's benefit and for research and pedagogical reasons. We will evaluate the practicality and necessity of using a more complete model of each student's knowledge so that the system can infer where the student needs more work or if any topics can be skipped.

5 Evaluation

We have three goals in this project. First, we want to replicate and extend the tutoring results of AutoTutor. Will tutoring be as effective (or more effective) in a different type of domain? Do the additional pedagogical strategies add to the effect? Second, because we are integrating the use of the system into the course, we are more concerned about the students' learning than we would be if we were just testing our approach. If the system significantly helps the students, we can expand it to other topics and other courses. If it doesn't help, it should be modified or eliminated. Finally, we want to gain information for improving this and other intelligent tutoring systems.

To evaluate RMT, we will assign students into one of two conditions. Participants in the experimental condition will be required to use the RMT system for a minimum amount of time between the discussion of each topic in the course and testing on it. The system's log will record how much time the students actually used the system, which topics they covered and the overall quality of the student responses. Participants in the control condition will use a web-based review system that gives the same material as the RMT system with a page-by-page presentation, and asks multiple choice questions at the end of each section. The total amount of time on the review system will also be logged, as will the scores on the tests. Results of the evaluation will be used to address the three goals mentioned above.

6 Conclusions

As mentioned above, we have several different goals with this project. We hope to build on the success of the AutoTutor approach to intelligent tutoring and apply it to a new domain. We have chosen research methods in Psychology because of the opportunities it provides to try out different pedagogical strategies. Because we also hope to integrate the system into the course's curriculum and make it one of the standard teaching tools for the course, we are committed to extending the abilities of the system in a variety of ways. Our evaluations will determine whether this is a good idea in the first place, and how the system can best meet the needs of the students.

References

[1] G. Biswas, D. Schwartz, J. Bransford, and The Teachable Agents Group at Vanderbilt. Technology support for complex problem solving: From SAD environments to AI. In K. Forbus and P Feltovich, editors, *Smart machines in education*, pages 71–98. AAAI Press, Menlo Park, CA, 2001.

[2] A. Britt, P. Wiemer-Hastings, A. Larson, and C. Perfetti. Using intelligent feedback to improve sourcing and integration in students' essays. *International Journal of Artificial Intelligence in Education*, 2003. under review.

[3] R. Freedman, Y. Zhou, M. Glass, J. Kim, and M. Evens. Using rule induction to assist in rule construction for a natural-language based intelligent tutoring system. In *Proceedings of the 20th Annual Conference of the Cognitive Science Society*, pages 362–367, Hillsdale, NJ, 1998. Erlbaum.

[4] A. Graesser, N. Person, D. Harter, and the TRG. Teaching tactics and dialog in AutoTutor. *International Journal of Artificial Intelligence in Education*, 12:23–39, 2001.

[5] A. Graesser, K. Wiemer-Hastings, P. Wiemer-Hastings, R. Kreuz, and the TRG. Autotutor: A simulation of a human tutor. *Journal of Cognitive Systems Research*, 1:35–51, 1999.

[6] A. C. Graesser, N. K. Person, and J. P. Magliano. Collaborative dialogue patterns in naturalistic one-to-one tutoring. *Applied Cognitive Psychology*, 9:359–387, 1995.

[7] N. T. Heffernan and K. R. Koedinger. An intelligent tutoring system incorporating a model of an experienced human tutor. In S. Cerri, G. Gouarderes, and F. Paraguacu, editors, *Proceedings of the 6th Annual Conference on Intelligent Tutoring Systems*. Springer, 2002.

[8] T.K. Landauer and S.T. Dumais. A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, 104:211–240, 1997.

[9] K. Malatesta, J. Robertson, and P. Wiemer-Hastings. Beyond the short answer question with research methods tutor. In S. Cerri, G. Gouarderes, and F. Paraguacu, editors, *Proceedings of the 6th Annual Conference on Intelligent Tutoring Systems*. Springer, 2002.

[10] N. K. Person. *An analysis of the examples that tutors generate during naturalistic one-to-one tutoring sessions*. PhD thesis, University of Memphis, Memphis, TN, 1994.

[11] C. Rosé, P. Jordan, M. Ringenberg, K. VanLehn S. Siler and, and A. Weinstein. Interactive conceptual tutoring in Atlas-Andes. In *Proceedings of AI in Education 2001 Conference*, 2001.

[12] R. Schank and A. Neaman. Motivation and failure in educational simulation design. In K. Forbus and P Feltovich, editors, *Smart machines in education*, pages 37–69. AAAI Press, Menlo Park, CA, 2001.

[13] Aleven V., O. Popescu, and K. R. Koedinger. Towards tutorial dialog to support self-explanation: Adding natural language understanding to a cognitive tutor. In *Proceedings of the 10th International Conference on Artificial Intelligence in Education*, 2001.

[14] P. Wiemer-Hastings, A. Graesser, D. Harter, and the Tutoring Research Group. The foundations and architecture of AutoTutor. In B. Goettl, H. Halff, C. Redfield, and V. Shute, editors, *Intelligent Tutoring Systems, Proceedings of the 4th International Conference*, pages 334–343, Berlin, 1998. Springer.

[15] C. Zinn, J. D. Moore, and M. Core. A 3-tier planning architecture for managing tutorial dialogue. In *Intelligent Tutoring Systems, Sixth International Conference (ITS 2002)*, 2002.