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Real-World Problem Solving Mathematics Tutor

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Abstract: A project is described involving the design of a web-based intelligent tutoring system for use in teaching complex problem-solving in mathematics for middle- and high-school students. A team of researchers and teachers from Texas A&M University and the South San Antonio Independent School District have developed a prototype of the complex problem-solving tutor for investigating the impact of promoting higher levels of real-world problem-solving skills through the delivery of a model-tracing tutor.

Keywords: complex problem-solving, intelligent tutors, mathematics instruction

Introduction

Researchers from the Cognition and Instructional Technologies Laboratories (CITL), located at Texas A&M University, and teachers from the South San Antonio Independent School District (ISD), located in San Antonio, Texas, are collaboratively researching, designing, and building a web-based intelligent tutoring system (ITS). The ITS software project is sponsored by the Air Force Office of Scientific Research (AFOSR) as an example of transitioning Department of Defense (DoD) ITS technology for use by schools. The objective of the 3-year research project is to collaboratively construct, verify, and apply a mathematics problem-solving thinking process in a web-based ITS application for middle- and high-school students. The real-world cognitive (or complex) problem-solving tutor in mathematics (CPS Tutor) operates via the World Wide Web (WWW) using intelligent tutoring technologies. After completing the first year of activities, the research team has designed a prototype of the CPS Tutor. The underlying theoretical framework of the CPS Tutor is based on the application of Sternberg's triarchic theory of intelligence as the pedagogical structure delivering problem-solving tutoring through the use of an Anderson Adaptive Control of Thought (ACT-R) model-tracing tutor design. The CPS Tutor will help to prepare teachers and to promote higher levels of real-world problem-solving skills by at-risk and economically disadvantaged students.

CPS Tutor Design

The recognition of the importance of complex problem solving, as a key component of educational reform, has grown considerably over the past decade (Nickerson, 1994). Educators recognize that students require explicit instruction on problem solving involving problems of suitable real-life complexity (see National Commission on Excellence in Education, 1983; and results of the Task Force on Mathematics and Science Achievement (TIMSS) created by the National Science Board, 1999). For years, the assumption was held that teaching secondary students to solve basic technical mathematics problems would implicitly enable them to learn thinking skills needed to solve complex real-life problems. Unfortunately, many students are not able to successfully acquire or apply the implicitly received instruction on abstract problem solving to real-life problems. Even with explicit "back-to-basics" instruction to recognize various mathematical problem types, students often struggle with determining relevancy and transferring the implicitly taught abstract "thinking steps" to solve problems encountered in life (see Tversky & Kahneman, 1974).

A six-step problem-solving model was designed to address the aforementioned challenges in teaching real-life problem-solving skills and to complement the framework for adaptive instruction provided by the project team's web-based tutoring system. The tutor will serve dual roles for both introducing and demonstrating to teachers and students a model for using complex problem-solving thinking processes to address real-life problems. The problems are organized into sets corresponding to targeted Texas Essential Knowledge and Skills (TEKS) for middle- and high-school mathematics. Each selected TEKS area is represented by a problem set containing problems arranged by difficulty level. Eight core problems span four difficulty levels within a problem set. Once a student successfully completes two core problems within a difficulty level they proceed to complete one of three randomly assigned problems before progressing on to the next level. Following the completion of all sets, the student enters the integration testing set wherein representative problems from across the included TEKS areas are provided. Teachers may also directly assigned any given problem from across any problem set to a student as a homework assignment included within the electronic student notebook. The CPS Tutor also provides an operating mode for instructional presentation of any problem by a teacher.

The South San Antonio ISD project team members include 6 middle-school, 4 high-school, 2 alternative mathematics teachers, and the District Director for Mathematics and Science. Working with CITL researchers, the team designed the following six-step problem-solving model:

(1) Comprehend the problem,
(2) Gather and process data and/or information,
(3) Design a plan of action,
(4) Implement a plan of action,
(5) Evaluate reasonableness and justify solution(s); and
(6) Communicate the solution.

Next, project teachers used the six-step problem-solving model to construct real-world mathematics problem sets for the software tutor. Authoring templates and software were developed by the project team to assist teachers in creating mathematics problems on the basis of the 6-step model. The authoring template includes paper and electronic versions of guided instructions for constructing the following information for each of the six steps associated with a problem: (a) Expected student input, (b) Coaching messages, (c) Glossary term(s), (d) Key words, (e) Formula, (f) Pop-up calculator(s), (g) Graphics, visuals, simulations, (h) Feedback and suggestions.

The problem sets are presented to the student using a process involving the following 10-sequence phases within the CPS Tutor:

(1) *Pre-test*: a representative problem of the set is presented as a pre-test;
(2) *Skill level assignment*: on the basis of how well the student performs on the pre-test, assignment is made to either the first or second problem-difficulty level;
(3) *Problem introduction*: on the basis of either the pre-test placement or on the basis of teacher assignment, the first problem is introduced from the set;
(4) *Problem type identification*: the student is then prompted to comprehend and reflect on the type of problem presented by the software (this is actually the first problem-solving step);
(5) *Six step problem-solving plan*: beginning with the previous activity on the comprehension of the problem, the student begins to respond to prompts for each of the steps in the problem-solving model;
(6) *Action step evaluation*: on the basis of inputs received from the student, the program evaluates problem-solving progress using the expected responses supplied by the instructor when the problem was created;
(7) *Coaching and hinting*: the student receives periodic coaching from the tutor to successfully complete all six steps of the problem-solving model (additional help can be obtained by requesting hints);
(8) *Solution generation*: the student continues with each step in the problem-solving model until a solution is generated;
(9) *Reflective follow-up*: on the completion of a solution the student is shown a summary of the work towards a solution and also a summary of the teacher's work towards a solution; and
(10) *Post*-test: the student progresses through the problem levels until the set is completed and then takes a post-test. The post-test result is then compared to the pre-test result to measure improvements.