British Journal of Educational Technology *Vol 35 No 1 2004* 107–109

Colloquium

Developing a computer-based peer tutoring system

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Introduction

Peer tutoring, whether it is different from reciprocal teaching and peer collaboration (Palincsar and Brown, 1984), has been studied for a long time because this method has allowed students to gain several cognitive benefits. For example, Bargh and Schul (1980) reported that students could learn better when they tried to teach others. Another study showed that there were several ways to help students engage in active learning in an environment supportive of effective learning (Wallace, 1996). The computer-based peer tutoring system discussed in this paper was also supported by a cognitive study that revealed a positive correlation between the use of self-explanation and learning capability for verbalisation (Chi *et al*, 1989).

Peer tutoring that involves the use of controlled procedures with highly structured material is called structured peer tutoring (Goodlad and Hirst, 1989). This paper presents how structured peer tutoring can be designed in a computing environment.

Design framework

A particular CAI (computer-aided instruction) that includes the following three modes is designed as a computer-based peer tutoring system in the domain of linear equation solving:

1. A presentation mode for practising materials in a step-by-step fashion
2. A teaching mode for rehearsing materials with annotated descriptions
3. A mixed initiative mode for guiding with immediate feedback from a computer coach

In this system, a student's role is reversed toward a teacher's competence after he or she gains initial competence. The student is expected to learn more toward the teacher's competence while explaining concepts with annotated descriptions and receiving feedback from the hidden coach. This design framework is somewhat similar to Chan's learning companion system (1989) which adopted three agents to stimulate student learning: a learning companion (computer companion), a computer coach and the student. Within this design, the learning companion collaborated with the student while the coach guided both the student and the learning companion.

Following this line of research, this study presents how to develop a prototype of a computer-based peer tutoring system and pursue its formative evaluation. With this system, students are expected to learn by examples with annotations provided by the computer. In other words, students can follow how a computer expert solves linear equations and thereby learn from working examples at the beginning. Later, students are expected to gain more expertise by explaining to the computer how to solve the problems. In short, the computer plays the role of an expert, while a student mimics the behaviour of a teacher. An interactive dialogue pops up when the hidden computer coach finds the student's misconceptions.

Switching to three-agent model

Typical educational software adopts a two-agent model: a learning agent (student) and a teaching expert (computer). The system in this study evolves from a two-agent model to a three-agent model (Card, 1989). Similar to the conventional ITS (intelligent tutoring systems), two agents initially communicate with each other by learning from examples. The computer expert demonstrates how to solve the problems, and the student imitates and approximates the computer's expertise in a step-by-step fashion according to the white-box design principle (Beeson, 1996). As soon as a human student completes watching the computer expert's demonstration, the transition to a three-agent model occurs in the 'Peer Tutoring Mode' where the student teacher, the computer learner and the computer coach interact.

Coaching only occurs when the human student engages in faulty teaching by choosing incorrect verbal annotations provided in a pop-up menu for each problem-solving step. Once the student gets stuck, a third agent (the computer coach) guides the student toward a solution by prescribed annotations. In this way, the human student can benefit from interacting with the computer learner and being guided by the computer coach.

Results of formative evaluation

Eight high school students in the United States participated in testing the prototype. Four students at two different high schools (School A and School B) participated in 30-minute interviews. It is noted that School A students were low-level students and that School B students were quick learners. Each student was encouraged to reveal any comments that might affect the future development of the system. For data analysis, a qualitative method was used to interpret interview data (Schofield *et al*, 1990).

The interview data contained the students' diverse reactions to the system through their self-awareness of using computers for problem solving. This brought up valuable lessons for the developmental processes of producing educationally meaningful software. First, the Peer Tutoring Mode elicited different reactions from both groups of students. For example, School B students, who were fast learners, felt that the prototype was too slow. They also mentioned that the use of pop-up menus was not so helpful in fostering comprehension and explanation. However, the opposite interpretation was drawn from School A students, who were slow learners. Second, it was also noted that human peer tutoring was quite different from the artificial peer tutoring, partially due

to the interface design driven by pop-up menus that facilitated communication between the human student-teacher and the computer learner. Third, the weak coaching strategies seemed to make School B students feel unsatisfied with the prototype. The overall responses revealed that the low-level students took advantage of gaining cognitive and attitude benefits from using the proposed system.

Summary and discussion

This paper explores the feasibility of a computerised peer tutoring system for school mathematics. By reflecting high school students' verbal descriptions, the design rationale of the peer tutoring system was mostly supported by the low-level students from School A, while School B students as quick learners indicated critical feedback on how to improve the Peer Tutoring Mode.

It is prominent that most of the students seemed to rely on the use of explanations and examples for their initial learning processes. Thus, the students were familiar with operating on the level of symbolic manipulation for tasks such as linear equations. The empirical findings of this study imply that it is necessary to pay attention to types of student learning and task complexity. Lessons learned from this study indicate how to improve the computer-based peer tutoring system. The modification of the computer coach requires several advanced coaching strategies that can keep track of each student's learning progress. Other suggestions include the addition of realistic conversation, picture, sound and even colour to the computer learner. These empirical findings direct the designer's attention to the future version of the prototype.

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