Effectiveness of Incorporating Mathematical Augmentation in Intelligent Dialogue-Based Tutoring System

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Introduction

Mathematical augmentation is the foundation and essence of mathematics education. Mathematical argumentation can not only promote deep mathematical understanding, but also learn to connect some abstract ideas in a logical way (Kuhn, 2005; Partnership for 21st Century Skills, 2008). Although argumentation is an important skill, it is not an innately possessed or can be easily acquired skill. Research showed that the performance of the argument is not good for most people (Hahn, Harris & Oaksford, 2012). Mathematical argumentation is often conducted in the classroom through group discussions (Osborne, 2010). Teachers with the professional skills in augmentation could guide students to carry out effective mathematical augmentation. However most teachers don't know how to implement argumentation teaching in mathematics class (Lin, 2018). Most students in classes are in the middle ability, a small number of students have high or low ability, and it is difficult to group students heterogeneously. Mathematical conjecturing has a power of construing a series of connected mathematics properties or mathematics concepts as an approach to enhancing mathematical argumentation. In this research, the mathematical conjecturing instruction is guided by a tutor agent in the intelligent dialogue-based tutoring system. According to students' abilities, different types of peer agents are used to solve the problem of grouping students heterogeneously in traditional classroom. The effectiveness of incorporating mathematical augmentation in intelligent dialogue-based tutoring system is explored in this study. The questions addressed in this study are: 1) Is the learning gains of incorporating mathematical augmentation in intelligent dialogue-based tutoring system more effective than that of traditional group based instruction? 2) Is the learning gains in mathematical conjecturing of the experiment group more effective than that of the control group?

Intelligent Dialogue-based Tutoring System

Mathematical Augmentation

Mathematical conjecturing is an approach to evoke mathematical argumentation as one aspect of mathematical literacy. Mathematical conjecturing illustrates mathematics as a language and mathematics as scientific pattern. The mathematical conjecturing includes four stages: guessing, testing, refuting, and believing. Guessing: build a conjecture; Testing: check his conjecture to include all known conditions or examples. Refuting: try to refute it with conditions or counterexamples. Conjectures refuted can be modified and re-entered for testing. Believing: believe this conjecture. These four mathematical conjecturing stages will incorporate into intelligent dialogue-based tutoring system in this research.

Incorporating Mathematical Augmentation in Intelligent Dialogue-Based Tutoring System

The dialogue-based intelligent tutoring system consisted of four submodules, domain module, student module, tutoring module, and interface module (Graesser, 2016) . The two agents, tutor agent and peer agent, dialogue-based intelligent tutoring system is developed in this study. In intelligent dialogue-based tutoring system development, the domain experts are responsible for constructing domain knowledge. In this study, the "Triangle Congruence and Similarity" unit of mathematics utilized in Taiwanese junior high schools is adopted by six domain experts, four practicing teachers in junior high schools and two professors in the mathematics education field, to construct tasks in the dialogue based intelligent tutoring system. By analyzing teaching materials and objectives, the eight tasks such as three sides equal (SSS) related to the Triangle Congruence and Similarity were constructed by the domain experts after many discussions in the domain module.

Mathematical conjecturing leads the tutoring module in the dialogue-based intelligent tutoring system. Taking three sides equal (SSS) as an example. Guessing: students and peer agent cooperate to operate the GeoGebra software (Fig.1) to create multiple triangle examples for students to observe and build a conjecture. Testing: according to the instruction of tutor agent, students try to combine triangles to test whether their guess is correct. Refuting: peer agent provides upside-down triangles to refute congruence. But it can still be superimposed after being reversed or rotated, so the refutation is not valid. Believing: by failing to find counterexamples in the process of testing to refute, make students believe in the conjecture.

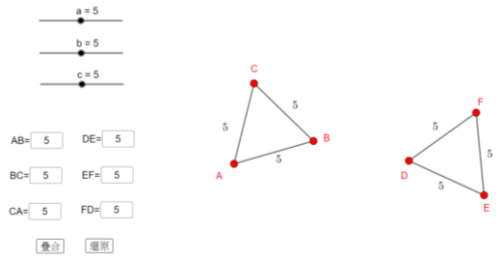

Fig.1 the GeoGebra software embedded in the Tutoring system

In the interface module, the graphics operations and algebraic symbols related to the Triangle Congruence and Similarity is designed to benefit learning for students. Some examples of the interface module were shown in Fig.2.

Fig.2 the interface of the tutoring system.

In the student module, the block-match analysis is applied to update the cognitive status of the student while learning Triangle Congruence and Similarity. According to the results in the pretest and the mathematics teaching material, the mathematics corpus of the Triangle Congruence and Similarity in the log file format was built in this research.

Field Experiment

The 68 students (experiment group: 35; control group: 33) from the ninth grade of Taiwanese junior high school were selected to participate in the field experiment in this study. The pre-test/post-test nonequivalent group design was adopted to evaluate the effectiveness of the incorporating mathematical augmentation intelligent dialogue-based tutoring system. Using each class as a unit, students were randomly assigned to the experiment groups and the control groups respectively .This study controlled relevant variables, such as grades, teaching hours, and teaching materials. When the Triangle Congruence and Similarity unit instruction was completed, all students had to take a pre-test on Triangle Congruence and Similarity, with its results being the covariate. The following week, all students took three additional instruction classes. In the experiment group, students learn Triangle Congruence and Similarity via two agents dialogue-based intelligent tutoring system. In the control group, traditional instruction of group-based is implemented. After both of additional classes were done, all students took post-test.

Data Analysis Procedure

Analysis of covariance (ANCOVA) is used to detect significant differences in learning gains between the experiment group and the control group. In ANCOVA, the pre-test scores are taken as the covariate and the post-test scores were taken as the dependent variable. The learning gains are the test score on post/pre-test related to the Triangle Congruence and Similarity.

Results

The questions addressed in this study are: 1) Is the learning gains of the incorporating mathematical augmentation in intelligent dialogue-based tutoring system more effective than that of traditional group based instruction? The results of ANCOVA indicated that the students with incorporating mathematical augmentation in intelligent dialogue-based tutoring system can get a higher score than that with traditional group-based instruction.

2) Is the learning gains in mathematical conjecturing of the experiment group more effective than that of the control group? In terms of guessing ability, the low-achievers with incorporating mathematical augmentation in intelligent dialogue-based tutoring system is better than that of the control group. In terms of testing ability, the students with incorporating mathematical augmentation in intelligent dialogue-based tutoring system is better than that of the control group. In terms of refuting ability, the students with incorporating mathematical augmentation in intelligent dialogue-based tutoring system is better than that of the control group.

SUMMARY

Incorporating mathematical augmentation in intelligent dialogue-based tutoring system is developed in this study. Mathematical conjecturing consisting of guessing, testing, refuting, and believing leads the tutoring module in the dialogue-based intelligent tutoring system. The two agents take on different roles, serving as a tutor agent to guide mathematical conjecturing procedure and a peer agent to cooperate with the student. The Triangle Congruence and Similarity introduced in junior high school in Taiwan is used as an example. The effectiveness of incorporating mathematical augmentation in intelligent dialogue-based tutoring system for learning mathematics in the field experiments are conducted in this research. Students who received incorporating mathematical augmentation in intelligent dialogue-based tutoring system outperformed those who received the traditional group-based program.

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