Dialogue-Based Intelligent Tutoring System for Mathematical Modeling in Regression Analysis

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Introduction

Mathematical modeling is an ability that has been widely valued in recent years. Take the United States as an example. In the Common Core State Standards Initiative for K-12 announced by CCSSO (Council of Chief State School Officers) and NGA Center (The National Governors Association Center for Best Practices) in 2010, mathematical modeling is one of the eight mathematical practice standards for mathematics education. In addition to the detailed statements of various mathematical standards, the initiative also proposed six key areas of overall K-12 mathematics education. Mathematical modeling is also one of them, which shows the importance of mathematical modeling.

Various international mathematical modeling competitions and other activities to promote mathematical modeling are also in the ascendant. For example, MCM (The Mathematical Contest in Modeling) ,HiMCM (The High School Mathematics Contest in Modeling), and IMMC (The International Mathematical Modeling Challenge). These competitions have once again demonstrated the importance of mathematical modeling.

With the increasing importance of mathematical modeling, many related studies and courses have been proposed (Lesh & Yoon, 2007; Niss, 2012). However, mathematical modeling is not a fixed teaching content, even if it is about the same problem. Modeling as a process (BorromeoFerri, 2006; Lesh & Yoon, 2007; Niss, 2012), if any step in the process changes, the subsequent processing is likely to be very different. Moreover, mathematical modeling generally does not have the so-called standard answer. How to implement mathematical modeling teaching at the teaching site is a considerable challenge. Therefore, if you can provide pre-prepared systematic and intelligent assistance in teaching, it will be of substantial help to the implementation of mathematical modeling in the educational field.

According to the relevant researches on mathematical modeling teaching and the rules of international mathematics competitions, it can be found that cooperative learning is a good way to conduct mathematical modeling teaching. On the other hand, AutoTutor is a dialogue-based intelligent tutoring system, which has succeeded in many applications. Therefore, this research will construct a dialogue-based intelligent team tutoring system with cooperative learning as the teaching mode to carry out the modeling teaching of university level regression analysis, and study the effectiveness of this system.

Mathematical Modeling

The so-called mathematical modeling refers to the process of abstracting specific problems in the real world, establishing mathematical models, using mathematical language, symbols, and methods to analyze, predict, suggest, verify, and solve problems (Blum,2002; Lesh & Doerr,2003). Many studies had shown that the process of modeling is a cyclical process (Lesh & Doerr, 2003; Blum & Leiss, 2005). Through the modeling cycle, students' mathematical modeling ability refers to the ability required to complete the mathematical modeling process.

Math and Regression Modeling Process

Although many studies have proposed their own mathematical modeling processes, with the increasing maturity of the discussion, the basic structures of most processes have become very similar. Considering the feasibility and implementation experience, and in view of the fact that COMAP (The Consortium for Mathematics and its Applications) has hosted mathematical modeling competitions since 1985, this study adopted the process proposed in the latest GAIMME (Guidelines for Assessment & Instruction in Mathematical Modeling Education) published by SIAM and COMAP in 2019.

The mathematical modeling process suggested by GAIMME is shown in Figure 1. It basically includes six main steps. These steps are not only one-way, but there are also many steps that can be adjusted in both directions to refine the entire solution.

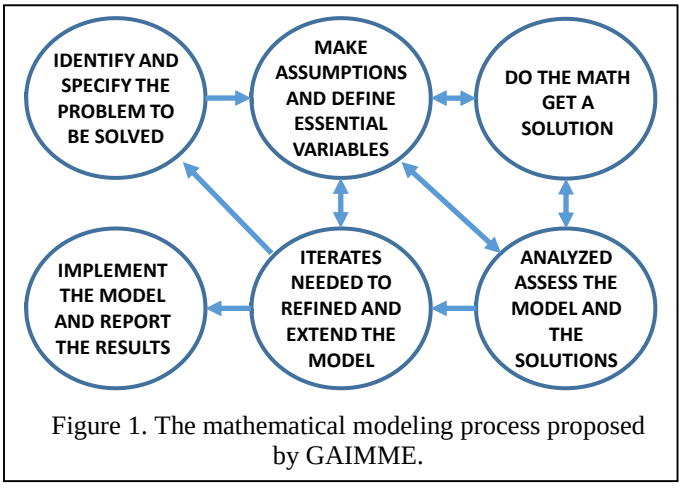

Figure 1. The mathematical modeling process proposed by GAIMME.

The establishment of regression analysis model can be regarded as a mathematical modeling process. Actually, the construction of a regression model is just one kind of mathematical modeling. It is a process rather than a single step task. The classic regression analysis textbook “Applied Linear Statistical Models” (Kutner et al., 2005) included a process of regression modeling. This process is quite consistent with the mathematical modeling process proposed by GAIMME. This research will integrate these two processes to design a regression modeling tutoring system.

Dialogue-Based Intelligent Tutoring System for Regression Modeling

This tutoring system was designed to lead learners to complete the modeling process step by step. The content of each step was built according to the six principles of modeling teaching activity design and model development sequence proposed by Lesh & Doerr (2003). These principles are: 1. The Personal Meaningfulness Principle; 2 The Model Construction Principle;

3. The Self-Evaluation Principle; 4. The Model-Externalization Principle; 5. The Simple Prototype Principle; and 6. The Model Generalization Principle. Besides, for increasing teaching performance, dialogues in the system were designed according to the 'Trialogue Designs for Pedagogical Agents' proposed by Graesser, A. C., Forsyth, C., & Lehman, B. (2017).

After integrating all the considerations, a dialogue based intelligent tutoring system for university students' mathematical modeling in regression was completed. One of the interfaces used in the system was illustrated as Figure 2.

Figure 2. One of the interfaces employed in the tutoring system.

Field Experiment

The subjects of this study are students who are studying regression analysis in the third year of university. The students come from two different classes, one of which has 71 people (the control group) and the other has 50 people (the experimental group). This study controlled relevant variables, such as grades, teaching hours, and teaching materials. After students have completed the relevant knowledge of simple linear regression analysis and regression modeling, the pre-test was carried out. The following week, all students took an additional instruction classes. In the experiment group, students learned regression modeling using the proposed dialogue-based intelligent tutoring system. In the control group, traditional group-based instruction was implemented. Then all students took post-test.

Data Analysis Procedure

Pairwise t-test and Analysis of Covariance (ANCOVA) were used to detect the differences in learning gains. Pairwise t-test was used to evaluate if there was significant difference between pre- and post-test. In ANCOVA, the pre-test scores are taken as the covariate, experiment group was adopted as the covariate, and the post-test scores were taken as the dependent variable. The interaction term was included in the model to detect if there is significant interaction.

Results

According to the results of pairwise t-test, the pre-test and post-test scores of the two teaching methods have improved significantly. This shows that both teaching methods are helpful for enhancing students' learning.

The results of ANCOVA shows: 1. There is significant interaction between groups and pre-test scores. So, students were divided into three clusters according to their pre-test scores percentile. Cluster 1 was composed of students whose pre-test scores was below the 33th percentile. Cluster 2 was composed of students whose pre-test scores was between the 33th and 66th percentile. Cluster 3 was composed of students whose pre-test scores was above the 66th percentile. 2. For Cluster1 (low pre-test score students), the interaction effect is not significant. The follow-up model (without interaction term) indicates that there is a significant different between two groups. The experiment group has better learning gain than the control group. 3. For Cluster 2 and Cluster 3, there is no significant different between the two groups.

SUMMARY

According to the experiment results, both the proposed dialogue based intelligent tutoring and the traditional group teaching can significantly improve students' learning performances in regression modeling. However, the improvement of students' learning gain is different according to the pre-test score. The proposed system has significant better performance for low pre-test score students (those below the 33th percentile). On the other hand, no significant differences are detected for other students.

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