Abstract

This paper presents an open user modeler called the mirror modeler that pretends to be the student and solves sample questions while the student watches mimicking student errors. This ability when added to an interactive teaching environment seems to greatly facilitate the learning process for two types of mathematical series while raising a serious question about the complexity of the third.

1. Introduction

“When a learner is engaged in a discussion about the learner model, he is reflecting upon his domain knowledge and experience re-calling and re-considering ideas of which he is aware.” [3]

Learner modelling is the process of trying to describe student performance in a particular task to help increase the efficiency of their learning. Morales, Pain and Ramscar [4] distinguish two basic types of representation for the learner’s cognitive state. Declarative representation, is a flexible way of storing knowledge that can be accessed for several applications and can be communicated. The second is Procedural representation, which encodes “execution” knowledge that is difficult to describe verbally. The idea is that discussing the model and/or actively participating in altering it, encourages students to verbalize their beliefs about their knowledge. This would turn, the “procedural” knowledge they were following in the task into “declarative” knowledge. The authors indicate that the modeling process must be analyzed with respect to viability, efficiency, and usefulness. Yet, it seems that testing for cognitive impact of this type of modeling is not such a straightforward task. Existing approaches for involving the learner in the modeling process include open learner models [5], collaborative student models [2] and interactive diagnosis [3].

Research into this field, has shown that Multi-Media Tutoring Systems as an example, offers strong support to student’s cognitive load. For example, in the case of Data Structures [1] were recorded improvements of up to 40% from post classroom levels. This raises an important question; if cognitive load can be supported through multi-media towards learning, then can a dynamic reproduction of their errors help in remediation?

2. Mirror Modeler

The model was developed using BM’s Java Visual Age for Java, which is an integrated visual development environment that facilitates the generation of complex functions. Its main features include the ability to import Graphical User Interfaces (GUIs) and Java Beans that could be constant throughout several applications. The tool generates java applets as in the case of this project or Java Servlets as is required.

2.1 The Problem: Mathematical Summation

Teaching can be in two directions; either giving students the Summation Notation and asking them to expand it giving the numbers on the right, or giving them
the numbers on the right and asking them to return the Summation Notation. The second task is of course, much more challenging than the first.

2.2 System Design

The system is composed of a tutorial section, a practice test section, test section, and a model comparison section.

The tutorial section of the system is composed of two main parts that introduce students to the concept of mathematical series. The system is interactive in that it allows students to select some of the variable values and generates the series accordingly whenever possible. The second part of the tutorial, is composed of examples to the more difficult task of extracting the notation from the series.

The practice test section is more interactive where students write the summation notation they believe to be the answer and are shown the resulting generated series. They can compare this series to the original and practice any number of times they wish.

The test section is similar to the above in that it has test questions given to students except that here, students are not shown the resulting series so they are not aware of whether or not their answers are correct. Student responses are then analyzed using an expert system that was specifically designed based on a field study of possible student errors in this task.

The student modeling component utilizes simple Bayesian rules to extract the probability for each type of error that student makes and it generates a descriptive verbal model with the results. Note that some errors have a dependency relationship to other errors and the expert rules are designed to reflect this relationship.

The modeler then shows students the ideal solution of each of the sample problems while regenerating how they would solve it using their models as a guide. The idea is to compare their behavior to that of the ideal and allow them to reflect on the causes of their errors.

3. Experiment

In order to understand the effectiveness of having an interactive user interface and an open student model, an experiment was performed to evaluate the amount and areas of student learning that occur in a controlled environment. Therefore, an experiment was performed using a pre and post test that are comparable in questions. Each student was given a paper and pen test prior to exposure to the system and following exposure.

12 students from the University of Bahrain participated as volunteers in return for course credit. The questions used were specifically selected such that they relate to each other in a way that could be later compared for further analysis.

Results showed that the number of errors made in the Pretest were 37 and the number of errors made in the Post-test were 17 with a probability of $p < .001$ of this happening by chance. Therefore, the system is capable of teaching students how to solve their mathematical series problems.

A more detailed study was made as per question type showing that students did better after using the system for Question Type One and Question Type Three, with $p < .01$ and $p < .0000$ respectively. On the other hand, students did worse in Question Type Two with $p < .001$. This raises a number of questions about the cognitive differences between the operations.

6. Conclusion

Students were better able to learn how to solve the questions with multiplication and division following the use of the system, while they did much worse in the problems that involved a “power” operation.

Simple operations such as addition, multiplication and power when placed in a series result in a big difference in student performance. Two of these seem to be learnable while the other, not. This requires further investigation into the cognitive tasks demanded by these operations and whether or not the mirror modeler resulted in this deterioration.

7. References