

The Relationship between Using of an Intelligent Tutoring System and Class Achievement in a Basic Mathematics Course

Abbass el Sharif and Ramzi A. Haraty

Lebanese American University/Department of Computer Science and Mathematics, Beirut, Lebanon

Abstract—In this paper, we present a case in which we integrated an intelligent tutoring system- ITS- in a basic mathematics course. The proposed ITS –PrivateTutor- is dynamic, web-based, adaptive, and interactive. It is composed of six different modules; each has a distinct function: student, domain, question, communication, expert, and controller modules. The purpose of this system is not to eliminate the role of human teachers, but to complement their effort in reaching all students and having one-to-one tutoring approach instead one-to-many. An experiment was conducted in order to study the effectiveness of PrivateTutor on class achievement. Students who were enrolled in a “Basic Mathematics” course in the Fall of 2005-2006 and Spring of 2006 at the Lebanese American University were randomly assigned to two groups: control and treatment. The experimental results failed to show any significant positive effect.

Index Terms—Intelligent Tutoring System, Moodle, Web-based Coach, and Private Tutor.

I. INTRODUCTION

This case is set in the Lebanese American University-LAU. LAU is a non-profit private American institution, whose main mission is to serve Lebanon and the Middle East area by “providing equal educational opportunities to all, developing life-long love of learning in students, and helping them become proficient in their fields” [4]. The educational system adopted by LAU is the American system for higher education.

LAU has four schools: School of Engineering and Architecture, School of Arts and Sciences, School of Business, and School of Pharmacy. The LAU student body, which represents 89 nationalities, is 6400 and consists of 51% boys and 49% girls. The faculty body, on the other hand, is 433 in which 71% of them have Ph.Ds [4].

LAU’s current strategic plan focuses on achieving academic excellence in teaching, learning and research. This strategic plan is also focusing on having better enrolment development program, using technology as a strategic tool for the implementation of change, and creating a marketing function that coordinates communication.

II. SETTING THE STAGE

The subjects of the study are freshman students of the Lebanese American University (LAU) in Beirut, Lebanon,

who are required to take the Basic Mathematics course (MTH111). Students come from different educational backgrounds (Lebanese, other local Arab systems, French, and American). Their desired majors vary from Communications Art to Biology, from Business to Political Science, Education, or Psychology. In summary, they are required to take this course in order to fulfill a general university requirement.

The course, Basic Mathematics, is a 3-credit course that provides a general background in numeration systems, logic, set theory, relations and functions, linear and quadratic equations, quantitative reasoning and probability. It aims at providing the student with the basic mathematical tools needed to tackle real-life situations. The learning outcomes of this course include the acquisition of a well-founded logic, the development of a mathematically solid analytical mind, and of systematic problem- solving scientific methodologies. The book adopted for this course is Mathematical Ideas [6]. The course is still taught in a traditional way; although there have been serious attempts to include technology in the way it is presented.

III. CASE DESCRIPTION

The Basic Mathematics course (MTH111) at LAU has always been taught in a traditional way, through which the professor comes to class, do his/her job in lecturing, assign homework to students, and then test them using the “paper and pencil” technology. This has made most students loose motivation to learn mathematics and as a consequence the class performance is low. The drop of interest could be matched to the following two reasons: First, the teacher stands in front of the class giving the lecture to more than thirty-five students at the same time. The session should be divided among them, and this means that each student will have less than two minutes to interact with the teacher. Furthermore, most of the times the students are passive and do not have the motivation to share their ideas with the instructor. The second reason is that the material is presented in a traditional way using the “black board” technology.

[1] defined the two-sigma problem, which states that “students who receive one-to-one instruction perform two standard deviations better than students who receive traditional classroom instruction.” This progress means that the average student who had private tutoring performed as well as the top two percent of that receiving traditional instruction.

It is not viable to have for each learner a teacher allocated for him/ her, and at the same time it is not useful to have one teacher lecturing to thirty-five students at the same time! So what is the solution?

One solution to this problem is to develop web-based intelligent tutoring systems that provide private adaptive tutoring. In this way, millions of students can access the tutor at the same time and from any place. This is more economical and efficient than assigning a teacher to every student.

In this case we present the design, architecture, and functionality for the proposed intelligent tutoring system. In addition to that, we discuss the experimental data that resulted from the integration of the system in the Basic Mathematics course.

IV. SYSTEM'S COMPONENTS

PrivateTutor is composed of six different components; each one has its distinct functionality:

1. Domain Manager: This manager represents the "pedagogical module" in traditional intelligent tutoring systems. The main purpose of this module is to manage the knowledge to be communicated to the student. In other words, this part of the ITS helps the course developer in structuring the lesson in a pedagogical way that follows the logical structure of the content. The lesson is presented to the student in an interesting way with animations and interactivity. At the end of each lesson, the student is evaluated through a question to check whether he/she has mastered the concept learned. If the concept is grasped, the lesson proceeds through its logical path; else the PrivateTutor directs the student to read and practice related prerequisite topics that deal with his/her missing conceptions. The settings of the lesson could be altered through the domain's manager interface. The course creator or the human teacher has the option to put time limits on each lesson. This timer does not force the student to leave the learning session for educational reasons; however, the lesson will be marked "unlearned" in the student's learning mastery record. This means that the student is supposed to take another session on the same topic. At the end of each lesson, a "Concept Check" section appears to check the student's mastery on the discussed topic. These results are stored in his/her mastery level record in order to make PrivateTutor adapt with his/her level of knowledge.

2. Question's Manager: This part of PrivateTutor is used to select and update the questions in the system's question base. Each question is associated with a difficulty level and according to this criterion the learner is presented with a question taking into consideration his/her mastery level. Many styles of questions could be asked: multiple choice, true/ false, short answer, numerical, and matching questions. The course creator can set a response to each answer in order to allow PrivateTutor give the learner positive feedback if he/she succeeded in answering the question, or a negative feedback with guidance.

3. Student's Model Manager: The student model manager tracks the student's activity during the learning session and stores his/her actions in the learning history database. Based on these records, the system classifies the student's level in a certain topic, and consequently the question manager selects questions labeled similar to the student's level for evaluation. A log file is created for each

student and is frequently updated. This file stores the time spent by the student on a reading activity, the number of attempts a student tries a given question, his/her grade, and the time he/she spent on solving it. In addition to this, the student model stores personal information about the user as well as his/her photo. The student's activity report could be used by both PrivateTutor and the human teacher to see the student's strengths and weaknesses.

4. Communication Manager: The communication manager is an interface between the system and the student. In our system, we have adopted Moodle-Modular Object-Oriented Dynamic Learning Environment – which is an open-source learning management system developed and maintained by [3]. [3] designed this software package to help educators post their courses online. Moodle has a lot of features that distinguished it from other course management systems:

- Each Moodle site can support more than one course.
- Moodle provides the developer with activity modules that he/she can use to support the implementation of the system.
- Moodle has 34 language packs (English, French, Arabic, Portuguese...), and this means that the user of any Moodle site can change the interface language based on his/her preference.
- It has a grading book that helps the instructor evaluate the student, by storing the latter's grades on each topic in the course.
- Moodle supports authentication mechanisms by allowing only registered students to use the system. This feature helps in tracking the student's performance by creating a personal profile to each one.
- Moodle has chat and forum modules to make students registered in a given course communicate and discuss issues related to the system's domain.

5. Expert System: *WebMathematica* has been chosen to underlie the expert module in PrivateTutor. *WebMathematica* "adds interactive calculations and visualization to a website by integrating *Mathematica* with the latest web server technology" [9] *WebMathematica* provides multiple input and output formats to the users by using commonly used web interface elements. Moreover, it provides server-based computations; hence no need to install additional software at the client's machine. The student can ask PrivateTutor any question no matter how much it is difficult. PrivateTutor uses the power of *WebMathematica* to do this job. It sends a request to *Mathematica* which in its turn answers the question, and then sends it back to the student via the communication module in a well-formatted layout.

6. Course Controller: This module is the heart of PrivateTutor. It is responsible for controlling the flow of information among its components. You can consider it a hub that resides in the middle of the system, where it is the only part that knows about the existence of other modules (domain manager, question manager, student model, expert system, and the communication model.) This course controller is also responsible for handling communication between the learners and PrivateTutor.

V. SYSTEM'S ARCHITECTURE

PrivateTutor's design is based on client-server architecture in order to serve millions of learners at the same time and from different places in the world. Figure 1 shows the system's design. The system is divided into six different components and four knowledge bases. The purpose behind dividing the database into four categories is to facilitate the process of course modification. This makes PrivateTutor classified an "open-architecture" system, i.e. it could be reused to teach other domains. According to [5], the separation of knowledge bases has "proved valuable in many AI-applications and eases modifications as well as configurability and reuse of the system."

PrivateTutor is platform-independent. In other words, the client or the learner does not need to install any additional software in his/her computer. The student needs only to have an internet browser (Netscape, Mozilla Firefox, or Internet Explorer...) for accessing the system.

PrivateTutor uses an Apache web server and MySQL relational database management system. The PHP script programming language is used to develop the system's components.

When the student starts using PrivateTutor, his/her computer sends an http request to PrivateTutor's servers. The course controller then checks the student model to see if the latter has a profile in order to get his/her mastery level and personal information. If he/she does not have one, then it prompts the student to register for an account. When learning a new topic, the course controller sends a request to the question manager to prepare a preliminary test in order to check the learner's mastery level. The domain manager is responsible for selecting the appropriate lesson or activity, while the quiz generator decides what questions to ask.

The constructivist theory has been adopted to be PrivateTutor's guideline for effective tutoring. The constructivist theory stresses on constructing knowledge in student's minds rather than reproducing it.

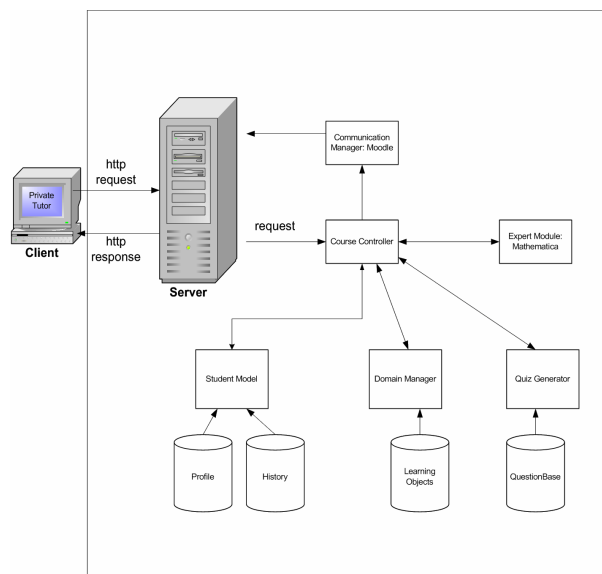


Figure 1. PrivateTutor Architecture

In other words, the student is supposed to build up this knowledge based on his/her "experiences, mental

structures, and beliefs that are used to interpret objects and events." This theory was developed by [2][7], and enhanced by [8] who stressed on social constructivism.

VI. USERS OF THE SYSTEM

Three types of users are allowed to interact with PrivateTutor: system administrators, teachers or course creators, and students (registered or guests). The first two types work on the server or development side, while the last works on the client side of the system.

1. System Administrator: The system administrator is the person responsible for managing and configuring the settings and variables of the tutoring system. His/Her main duties are as follows:

- Creating and managing the four types of knowledgebase
- Maintaining the proper work of the tutor by monitoring the user's and system's operations
- Setting up the site themes in a way that suits the learner's style
- Configuring and scheduling automatic backups
- Creating teachers and administrators accounts
- Managing the "chat" and "forum" modules

2. Teachers: There are two main responsibilities for the human teachers or educators in PrivateTutor. The first is to manage and edit the course that has been created by the administrator of the system. The teacher feeds the system with the logical structure of the course, and the responses that the ITS is supposed to give as a feedback to the student in a given situation. The second duty of the educator is to communicate with the learner via the system's chat rooms and forums.

3. Students: The main target of the system is the student. There are two kinds of students: registered students and guests. Any student can have full access to the system only if he/she has an account; else he/she is provided with limited features and activities. A registered student can browse, learn, and do exercises during a learning session, and all of actions are stored in the learning history database.

VII. EXPERIMENTAL METHOD

A. Hypothesis

The null hypothesis for this case is H_0 and will be tested against H_1 :

H_0 : The use of PrivateTutor by the students in the basic mathematics class will result in **no change** in class performance.

H_1 : The use of PrivateTutor by the students in the basic mathematics class will have **positive effect** on class performance.

B. Sample

The target population of the study is the set of students who are required to take a course on basic mathematics at the freshman level and enrolled in Middle Eastern universities that follows the American educational system. The accessible population for this case is the set of freshman students who took the Basic Mathematics course (MTH111) at the Lebanese American University in Beirut, Lebanon.

Students come from different educational backgrounds (Lebanese, other local Arab systems, French, and American). Their desired majors vary from Communications Art to Biology, from Business to Political Science, Education, or Psychology. In summary, they are required to take this course in order to fulfill a general university requirement.

The number of participants in this study is 71 students (62% females, 38% males) who were enrolled in two MTH111 sections during fall 2005-2006 and spring 2006 semester. The teacher of these two sections is the first author. The subjects split “naturally” into two groups: control group (35 students) and treatment group (34 students). The natural split is due to the following reasons:

- The teacher of both sections is the same.
- Students did not know the identity of the instructor before registering in the class.

C. Measures

The student performance was assessed based their final average of exams, quizzes and assignments. The first author taught both the control and the experimental group: Both sections were taught three times a week giving them the same material, assignments, quizzes and exams. Students were given daily assignments, weekly quizzes and three exams during the academic semester.

D. Design

In this case, a post-test randomized experimental design was used which can be summarized as follows:

R X O

R O

where R represents the randomly assigned groups, O represents the measurement (student’s exams) and X stands for the integration of the intelligent tutor.

This type of experimental design gets rid of almost all of the threats to the internal validity of the experiment (maturation, testing, instrumentation, selection, and mortality).

E. Procedure

The experimental group students were first trained to use PrivateTutor in a computer lab. They were asked to use PrivateTutor at home at least once a week. Based on the log files, the professor was able to check who is using the system and who is not. Course assignments were uploaded to the system, and some of the quizzes were online, but the midterms were paper-based. The control group on the other hand was not exposed to PrivateTutor, but they were given the same course material.

VIII. RESULTS AND DISCUSSION

To analyze the collected data (exams and quizzes) and determine the comparative results of class achievement with and without PrivateTutor, we used a t-test utilized at 5% level of significance. The results were as follows:

Groups	Mean of “Average Grades”	Variance	Sample Size
Control	78.8	208.4	35
Experimental	81.64	160.35	34

The degree of freedom in this experiment is ($df = 67$). The critical t-value is ($t = 1.98$) and the calculated t-value is ($t = 0.871$). Since the calculated t-value is less than the critical t-value, then we failed to reject the NULL hypothesis (H_0). In other words, the t-test results do not support the hypothesis which states that using PrivateTutor would affect positively on the class achievement in a basic mathematics course.

Although most of the experimental group students showed their interests in PrivateTutor and its learning activities, the above discussed experimental results showed that the integration of this system in basic mathematics courses failed to make a significant improvement. This can be because of many reasons: the system was not efficiently used by the students, or the system is not well-designed.

IX. CONCLUSION

In this case, we have presented a case in which we integrated an intelligent tutoring system into basic mathematics class. The first version of PrivateTutor is used to check whether class achievement can be improved upon using it. It turned out that this treatment does not support the predictions.

The current version of PrivateTutor is adaptive but not totally “intelligent”. It is not intelligent because it lacks the power of sensation and diagnosis. On the other hand, it has the ability to judge the student’s performance and give individualized tutoring based on his/her learning history. The student model can be enhanced in order to generate more intelligent behavior by extending its mechanism so that the system can analyze and do diagnosis on the student’s input in order to check out what his/her misconceptions and missing concepts are.

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