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The Use of an Interactive Website as an Assistive Technology in University Calculus Courses: A Synergist for Teaching and Learning?

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The Use of an Interactive Website as an Assistive Technology in University Calculus Courses: A Synergist for Teaching and Learning?

Nina Hayfa

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Abstract

University educators are in continuous search for ways to enhance student learning of mathematical concepts and to facilitate teachers' instructions of such concepts. Calculus is one of the most commonly taught mathematical subjects at university level. As such, we selected to investigate in our study the effect of an interactive website, www.mymathlab.com, on the teaching and learning of university Calculus. The teaching - learning approach evaluated here is likely to be the first of its kind in the Lebanese University Context and possibly beyond. Though many researches have been done concerning technology integration in mathematics education, most of this research was done at school level and not at university level. Moreover, research done at university level primarily touched on mathematical software as an assistive tool inside classrooms. The aim of our research was to identify if the use of such a website increases academic achievement in university calculus courses and if it facilitates teaching of calculus courses at university.

Two theoretical frameworks were used concurrently: The Variation Theory and the *Technological Pedagogical Content Knowledge (TPACK) Theory*. TPACK was used to study teacher's attitudes, while the variation theory was used to check the effectiveness of this website on enhancing student learning. Our study followed a quasi-experimental design of 2 groups: the experimental group (treatment group with www.mymathlab.com) and the control group (non-treatment group). Six sections of calculus were selected, and 3 instructors were chosen, each teaching two sections (experimental and control).

Student t- tests as well as an ANOVA study were used to compare student's academic results in the different calculus sections. The statistics obtained showed that this website significantly increased student achievement on calculus courses. A correlation analysis followed to show the relation between students' and teachers' attitudes and students' calculus grades. The regression model yielded a strong significance.

Keywords: Mathematics Education, University Calculus, Assistive Technology, Variation Theory, TPACK

Introduction

In the past years, the introduction of technology has changed many aspects of our daily life, including education. Mathematics, being an integral subject in our educational curricula, was exposed to the effects of technology (Fouts, 2000). The fact that a lot of factors are responsible for students' achievement in mathematics is not new to researchers but amongst those factors could be the use of technology as an educational tool and a possible synergist for teaching and learning.

The uses of technology in mathematics education started with calculators and developed to computers, video-conferencing, electronic whiteboards, interactive websites, etc…However, if one was to probe backwards in history, one is to find assistive technology has always been there one way or the other. The Sumerians invented the Abacus, a calculating board of columns with beads. The Incans, furthermore, developed the Quipu, a base-10 counting system made of counting fibers (Bebell, 2005)

From the old days of the Abacus and Quipu, to nowadays with computer software, electronic whiteboards and interactive websites, a debate about the effect of technology on education has erupted, dividing those concerned into two groups: proponents advocating the advantages and positive impact of technology on mathematics education-with a belief that technology helps students to process and develop information, to find alternative solutions, to take an active part in the learning process and to develop their problem solving skills- and critics listing the risks, disadvantages and costs of using technology in mathematics.

Statement of the Problem

University educators are in continuous search for ways to enhance student learning of mathematical concepts and to facilitate teachers' instructions of such concepts. With the emerging rise of technology in the 21st century, it was imperative to study the impact of technology on math education at university level.

Calculus is one of the most commonly taught mathematical subjects at university level. Students often face difficulties with this subject- a problem which forces educators to seek solutions that will help improve the teaching and learning of calculus at universities.

As such, we selected to investigate in our study the effect of an assistive technology interactive website, www.mymathlab.com, on the teaching and learning of university Calculus.

Tool to be Used

The assistive technology interactive website to be used is www.mymathlab.com. This website engages students in active learning: it is modular, self-paced, accessible anywhere with internet access, and adaptable to each student's learning style. Instructors can easily customize the website to better suit their students' needs.

MyMathLab offers a series of text-specific online courses designed to work with Pearson textbooks in mathematics. MyMathLab immerses students in an active learning environment at the time and place most convenient to them, and according to the learning style and pace that best suit them. Through the use of MyMathLab's automated assessment features, students know immediately if they're on track and if not, how to get back on track; instructors can quickly intervene at the first sign of trouble; and there is no risk of sudden surprises at the end of the semester.

Tightly integrated with the assigned textbook, MyMathLab offers a customizable set of course materials and adaptable instruction tools that allow the instructors to offer the entire program, a portion of the program, or just the homework option. Features include extensive online tutorial exercises, online homework assignments that are graded automatically, personalized study plans for students based on their test or quiz results, and online math tutoring.

Review of Literature

Advantages and Disadvantages of Technology

Proponents of educational technology contend that technology accommodates individual learning rates and styles and offers access to learning at any time and in any location (Peck and Jobe, 2008). They believe that the use of technology in the classroom provides students with the opportunity to (Eadie, 2001):

- Acquire the technological skills they will need for future employment;
- Develop critical thinking, problem-solving, and communication skills;
- Collaborate with peers;
- Engage in hands-on learning activities;
- Receive immediate feedback.

On the other hand, critics list a host of reasons why technology should not be emphasized (Grayson, 2004; Waddoups, 2004; Gahala, 2001; Healey, 2001):

- Risks of eye problems
- Costly, since the equipment requires extensive support

- Eliminates the role of teachers
- Student does not get corrective feedback on what he/she is doing.

Technology in Mathematics Education

Kauchak and Eggen (2008) pointed out that the use of technology is "changing both teaching and learning in the 21st century and controversies exist about its application." They go further to report that one of the dilemmas teachers encounter when they try to teach their students to solve problems is the difficulty of constructing realistic complex problems for them.

Technology is an important instrument in teaching and learning mathematics which enhances efficiency, communication, research, problem solving, and decision making (Niess, 2005)- hence supporting students in their understanding and appreciation of mathematics. It has been recognized by several authors and experts in educational management that students can learn more mathematics more deeply with the appropriate and responsible use of technology". Jurdak (2004) investigated the impact of technological apparatus, particularly computers, as facilitators in problem solving in mathematics education, and stated that technology can serve as a power for building bridges between abstract mathematics and problem solving in real life.

Technology and Mathematics Teachers Beliefs

Several studies have been conducted to understand how technology is used in classroom environments (Mkomange, 2012), which beliefs teachers hold towards teaching and learning with technology, how technology could support learners (Bishaw, 2010), and the know-how needed to integrate technology into the curriculum.

The role of information and communication technology is seen as a support and an enhancement of the ability of the teachers to solve mathematical problems. Most importantly, it changed the way the teachers see the problems and how they devise ways of teaching mathematical problem solving using technology in order to offer new and powerful learning environments.

Technology and Academic Achievement

There are numerous studies that have been conducted that show a positive relationship between the use of technology and academic achievement. For example, in an Illinois blue collar rural community, that used technology in mathematics education, math achievement levels (computation and problem solving skills) improved as well as student interest among elementary and secondary school students (Bishaw, 2010).

While many studies offer compelling examples of the ways that technology-based learning strategies may support academic achievement, not all studies yield positive results. Substantial literature also proposes that the use of technology as a learning tool may have drawbacks (Niess, 2005).

Theoretical Framework of the Study

Technological Pedagogical Content Knowledge (TPACK), builds on Shulman's idea of PCK, and attempts to capture some of the essential qualities of knowledge required by teachers for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge. At the heart of the TPACK framework, is the complex interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK) (Koehler & Punya, 2014).

Effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between all three components. A teacher capable of negotiating these relationships represents a form of expertise different from and greater than, the knowledge of a disciplinary expert (a mathematician), a technology expert (a computer scientist) and a pedagogical expert (an experienced educator) (Koehler & Punya, 2014).

Based on the TPACK framework, we are aiming in our study to show that the use of www.mymathlab.com will:

I. ***Design and develop technology enhanced mathematics learning environments and experiences.*** Educators use their knowledge of technology, pedagogy, and content to design and develop learning environments and experiences to maximize mathematics learning. Educators:

a. Establish and utilize mathematical environments, tasks, experiences and resources to integrate technology tools that support learners' individual and collaborative mathematical learning and creativity;

b. Design challenging and engaging mathematical learning experiences that utilize appropriate technologies to support the diverse needs of learners;

c. Identify and utilize strategies and activities that promote equitable access to and facility with technology resources.

II. ***Facilitate mathematics instruction with technology as an integrated tool:*** Educators implement curricular plans that integrate appropriate technology to maximize mathematical learning and creativity. Educators:

a. Incorporate knowledge of learner characteristics, orientation, and thinking to foster learning of mathematics with technology;

b. Facilitate technology-enriched, mathematical experiences that foster creativity, develop conceptual understanding, and cultivate higher order thinking skills;

Another theoretical framework will be used concurrently, which is the Variation Theory. TPACK will be used to study teachers' attitudes in terms of pedagogical, technological and content knowledge, while the variation theory will be used to check the effectiveness of this website on enhancing student learning. Instructors are constantly baffled by the fact that two students who are sitting in the same class, who have access to the same materials, can come to understand a particular mathematical concept differently. Variation theory offers a theoretical framework from which one can explore possible variations in learning experiences and the resulting differences in learning and understanding. According to the variation theory, there are a limited number of features of a given phenomenon to which we can pay attention at any given time (Watson & Mason, 2006).

As such, building on the Variation Theory, we are aiming in our study to show that the use of www.mymathlab.com will:

I. Design and develop different exercises on the same mathematical concept based on different approaches: the visual, the algebraic, and the geometrical.

II. Design and develop different exercises showing the "what" and the "how" of the mathematical objects being taught.

Hypotheses

The following null hypotheses were tested:

a. The use of an assistive technology interactive website in university Calculus courses will have no significant effect on students' academic achievements and concept understanding.
b. The use of an assistive technology interactive website will have no significant effect on supporting and enhancing teachers' class lectures and teaching skills (teaching skills stand for content and pedagogical knowledge of teachers) concerning calculus courses at university.

Methodology

Research Design

This study used a quasi-experimental mixed method design of 2 groups: the experimental group (treatment group with www.mymathlab.com) and the control group (non-treatment group). Specifically, the pre-test/post-test control group design (PPCGD) was used in this study. The PPCGD is a factorial mixed design widely used in educational and social sciences. The table below summarizes the PPCGD model (Creswell, 2013):

Table 1. *PPCGD Model*

Groups	Pre-test	Process	Post-test
E_1	O_1	X	O_2
E_2	O_3	-	O_4

As can be seen in Table 1, notations are: E_1= Experimental Group, E_2= Control Group, O_1 & O_2= Pre-test and Post-test Scores for the Experimental

Group, O_3 & O_4= Pre-test and Post-test Scores for the Experimental Group, X= process that stands for the experimental treatment which is the interactive website www.mymathlab.com.

Six sections of Calculus I were selected, and 3 instructors assigned, each teaching two sections (experimental and control). All sections were taught the same chapter (Integrals and Their Applications) during the same time duration (4 weeks) at exactly the same time. They were subjected to the same exams at the beginning (pre-test) and the end (post-test) of the study. The reason behind the above choice is the following:

1. By having the same instructor teach the two sections (experimental and control), we tried to eliminate the instructor's effect (varied teaching style effect) when we were to compare the results of the experimental versus the control groups.
2. By having 3 different instructors teach the six sections, we tried to eliminate also the effect of the teaching style at the end when we were to compare the groups among each other.
3. The choice of the website was due to the fact that it is a user-friendly interface and requires minimal IT knowledge. This served to eliminate the effect of pre-requisite IT knowledge on the results.

Procedure

The procedure used to conduct this research was comprised of six steps:

Step 1) Consider the 6 sections taught by 3 instructors: randomly select the 3 experimental groups and the 3 control groups such that each instructor is teaching one of each of the 2 groups.

Step 2) Introduce the www.mymathlab.com website for the experimental group

Step 3) Compare student results on exams for the two groups

Step 4) Conduct a survey to check teachers' attitudes. During the survey, we will check:

a. Does the website facilitate teaching?
b. Are teachers comfortable using it?
c. Do teachers have a need for training to be able to use it better?
d. Is using this website cost effective? (time, effort, etc..)

Step 5) Monitor the progress of students on the website (time, use of extra resources, etc…).

Step 6) summarize and interpret data

Step 7) Formulate conclusions and recommend future studies

Participants

The participants in this study were 150 students (N=150) enrolled in Calculus I, divided into 6 sections with 25 students each (n=25). The participants consisted of students entering into the first year of university, after graduating from high school, that is, students between the ages of 17 to 19. Students self-register for courses at the university; therefore random assignment to the control group or the experimental group could not be made. The experimental group was made of 3 sections and the control group was made of 3 sections. Each of the groups consisted of a total of 75 students. The treatment lasted for 4 weeks (a total of 12 teaching sessions) in which the chapter about Integrals and their Applications was introduced. All students received similar instruction through traditional lecture in the classroom and took the same pre-test and post-test. The control group students (3 sections) were assigned homework from the book to be submitted on paper to the instructor. The experimental group students (3 sections) used a customizable online text-book based interactive website, www.mymathlab.com. When students purchase the book, they have an access code and are given a course ID by their instructor. They then register and can access the system 24 hours a day from any computer that has an internet connection. Homework assignments were created from an online exercise bank that correlates to textbook exercises, and the questions are algorithmically generated which allows for unlimited practice and mastery. After attempting to work a problem, students receive immediate feedback. The system informs the students that the problem is correct or provides some type of instructional hint. Instructors can set the number of attempts a student has to complete a question. In addition to the immediate feedback, students have several learning aids to further assist them. One is the “Help Me Solve This” feature. When students click on this feature, another window opens and they are guided step by step through the same problem they are trying to solve, answering questions along the way. After the students are guided through this problem, when they return to the homework, they are given a similar problem to do on their own. Another feature is the “View an Example” that shows students a completely worked out example of the same type and scope of the problem they are attempting to solve. After viewing an example, students can then return to working on their original problem. A third feature is “Ask My Instructor” that allows students to ask their instructor by email about the question they are facing problems with.

Instrumentation

Three different instructors taught two sections each of Calculus I during the Fall 2013-2014 semester. The sections of the course for this study were face-to-face lecture-based classes meeting three hours each week. Each instructor had a control section and an experimental section for this study, with random assignment of sections being made. For the experimental section, there were a total of 5 online homework assignments and the number of questions per assignment ranged from 10 to 20 questions. The homework assignments were similarly aligned, and the questions on each assignment were a combination of multiple choice and free response questions. For the control section, the students were given 5 paper-based homework assignments based on exercises from the book and the number of questions ranged also from 10 to 20 questions, where the questions were a combination of multiple choice and free response questions.

The pre-test was prepared by the three instructors and was given to all students prior to starting the chapter to ensure that the groups were homogeneous. It consisted of 10 multiple choice questions and 10 free response problems. The aim of the pretest was to determine the pre-requisite knowledge of the students. The post-test was given after 4 weeks, when the chapter on Integrals and Their Applications ended. In order to make pre-test/post-test comparisons, the post-test had to align with the pre-test. As such, it consisted of 10 multiple choice questions and 10 free response problems. The content of this test matched the objectives of the chapter and were of the same scope and difficulty levels of the questions in the pre-test. Since the sections met on different times, the pre-test and post-test were given on the same time, same day.

This was also followed with a survey for the 3 instructors to determine whether this interactive website had a significant effect on supporting and enhancing teachers' class lectures and teaching skills (teaching skills stand for content and pedagogical knowledge of teachers) concerning calculus courses at university. The survey consisted of 7 questions following a Likert scale from 1 to 5 (with 1 being Strongly Disagree, 2 being Disagree, 3 being No Opinion, 4 being Agree and 5 being Strongly Agree).

Consent and Ethical Considerations

Having one of the researchers as the chairperson of the department, there was no need to secure the approval from the mathematics department to run this research. Also, following university rules, by joining a calculus course, students agree to the content of its syllabus. Should they disagree, they have the liberty of switching sections during the first week. As such, staying in class is an automatic consent to the content of the syllabus. Since the course syllabi included the usage of the website, there was no need for securing individual student consent. However, a consent letter from the 3 participating instructors will be obtained.

To safeguard the confidentiality of the participating university, the name of the university will be referred to as University X. Also to safeguard the confidentiality of the participating instructors, the names will be referred to as instructors P, Q, and R. Furthermore, to safeguard the confidentiality of the students, they will be referred to if need be with a combination of a number and a letter (for example, student 12PE is the student number 12 for instructor P in the Experimental section E, while 12PC is the student number 12 for instructor P in the Control section C).

Data Analysis

Means and standard deviations (SD) for the pretest and post test scores for the 6 sections are shown in Table 2.

Table 2. *Pre-test and Post-test Averages per Section*

	Control Section				Experimental Section			
	Pre-test		Post-test		Pre-test		Post-test	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
P	76.6	18.8	79.3	15.4	75.4	14.6	88.3	10.2
Q	73.2	16.3	78.4	19.2	76.8	15.2	89.2	11.3
R	74.3	19.5	77.5	16.7	73.1	14.9	87.5	9.8

An ANOVA study of the pre-test results for the 6 sections at a 0.05 level of significance (α=0.05, F= 1.24 with a p-value of 0.725) showed us that there is no statistical difference in the mathematical ability of the students concerning the pre-requisite concepts needed to study integrals between the groups. When the treatment was done, a paired t-test study between the pre-test and post-test scores for every section with α=0.05 was performed to determine if the interactive website made an effect on student achievements. The control sections gave a t= 0.25 with a p-value of 0.805, thus implying that there was no statistical difference in student achievement, while the experimental sections gave a t=2.78 with a p-value of 0.03, thus implying that the use of the interactive website significantly affected student achievement. The above results served to reject our first null hypothesis, which was that the use of an assistive technology interactive website in university Calculus courses will have no significant effect on students' academic achievements and concept understanding. Apparently, we can see that this website helped improve student achievement.

As for teachers' attitudes towards using this website, the survey results were documented in the table below (each tick represents an instructor's response):

Table 3. *Survey Questions and Responses*

	Strongly Disagree (1)	Disagree (2)	No Opinion (3)	Agree (4)	Strongly Agree (5)
1. The website allowed me to adapt my teaching in class based on what students understood or did not understand on the online homework				✓✓	✓
2. The website allowed me to adapt my teaching style to different learners.				✓	✓✓
3. The website allowed me to assess student learning in multiple ways					✓✓✓
4. The website allowed me to use a wide range of teaching approaches in a classroom setting.			✓	✓	✓
5. The website allowed me to become more familiar with common student understanding and misconceptions.				✓✓✓	
6. The website allowed me to select effective teaching methods to guide student thinking.			✓		✓✓
7. The website allowed me to understand technologies that I can use to do mathematics.				✓✓	✓

A thorough consideration of the answers above help to reject the second null hypothesis that the use of an assistive technology interactive website will have no significant effect on supporting and enhancing teachers' class lectures and teaching skills (teaching skills stand for content and pedagogical knowledge of teachers) concerning calculus courses at university. Apparently we can observe that the use of this website had a positive effect on the teaching skills and on enhancing teaching approaches in the classroom. The answers of these three instructors reflect a general agreement trend that the use of such a website has affected the Technological, Pedagogical, and Content Knowledge of the teachers involved. Effective technology integration through this website required teachers to develop sensitivity to the dynamic, transactional relationship between all three components of knowledge mentioned above.

Limitations of the Study

Several limitations existed within the study. The findings of this study may have limited generalizations since the data were drawn from one calculus topic only. However, similar studies performed by both authors are being repeated for the last 5 months on many calculus topics, and results up till now match the above findings. Moreover, the introduction of assistive technology may change other variables, such as teachers' roles, levels of student collaboration, and students' study habits. Though we tried as much as possible in this study to eliminate these effects, they cannot be totally controlled. Another limitation is the fact that this study tends to focus on just four weeks of implementation instead of several years, which would more accurately assess a program's impact on students and teachers. Furthermore, though this research attempts to conserve the minimum conditions of internal validity, it is a pilot study that cannot yet be tested for external validity since it was done at one university only.

Conclusions

The fundamental aim of this study was to investigate the effects of the use of an interactive assistive technology website, www.mymathlab.com, on the teaching and learning of university Calculus. To the latter end (that of learning Calculus), the scores obtained from the pre-test and post- test administered to the experimental and control groups were compared. It was revealed from the results of the scores obtained that there was a significant difference between the post test scores according to the pretest scores of the experimental and control groups, thus leading to a rejection of the first null hypothesis, which was that the use of an assistive technology interactive website in university Calculus courses will have no significant effect on students' academic achievements and concept understanding. Apparently, we could see that this website helped improve student achievement.

As for the aim of investigating the effects on the teaching of Calculus, a survey was run for the 3 instructors involved in this study. Thorough consideration of the results of the survey showed that the instructors mostly felt that this interactive website had a significant effect on supporting and enhancing teachers' class lectures and teaching skills (teaching skills stand for content and pedagogical knowledge of teachers) concerning calculus courses at university.

The outcomes of this study may have national and international implications for the integration of assistive technology interactive websites in Calculus courses. The teaching - learning approach evaluated here is likely to be the first of its kind in the Lebanese Context and possibly beyond. Though many researches have been done concerning technology integration in mathematics education, most of this research was done at school level and not at university level. Moreover, research done at university level primarily touched on mathematical software as an assistive tool inside classrooms. At the national level, the introduction of this teaching- learning model has the potential to contribute to math education at university level and provide a blue print for the design and development of calculus courses at university. At the international level, the research findings on the efficiency of this model could have for an implication, the provision of alternative pathways to identify student weaknesses in calculus and adjust teaching strategies at universities accordingly. This could in turn lead to improved student attitudes towards learning mathematics at university and an improved enrollment of students in math courses and math- related career paths.

Finally, this research opens the door for other possible research investigations. This study was done at one university only; the website could be introduced at other universities and the results of different universities could be compared for validation of the findings. Moreover, the duration of this research was limited to four weeks. In other future studies, we could monitor the results of students using this website over many semesters and compare their academic achievement over time. Furthermore, in our study, only one website is used. In the future, we may be able to use a different website, or use a different technology tool, and compare the results of the two websites concerning the teaching-learning model.

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