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Does the Timing of Feedback Affect Student Learning?

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DOES THE TIMING OF FEEDBACK AFFECT STUDENT LEARNING?

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment
of the requirements for the degree of
Master of Natural Sciences

in

The Interdepartmental Program in Natural Sciences

by
Tamara Hebert
B.S., University of New Orleans, 2005
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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
LIST OF TABLES	iv
LIST OF FIGURES	v
ABSTRACT.....	vi
CHAPTER 1. INTRODUCTION	1
CHAPTER 2. LITERATURE REVIEW	3
2.1 Discussion about Online Learning.....	3
2.2 Immediate Feedback versus Delayed Feedback	5
CHAPTER 3. THE STUDY	9
3.1 Characteristics of the School.....	9
3.2 Characteristics of the Mathematics Available at the School	9
3.3 Subjects	11
3.4 Course.....	12
3.5 Research Design	13
3.6 Pre- and Posttests.....	17
CHAPTER 4. METHOD	19
4.1 Prior to the Study.....	19
4.2 Pilots.....	20
4.3 Experiments.....	22
CHAPTER 5. DATA ANALYSIS	24
5.1 Data from Trial 1	24
5.2 Data from Trial 2	25
5.3 Final Results and Inferences	27
CHAPTER 6. CONCLUSION.....	28
6.1 Discussion	28
6.2 Recommendations	31
REFERENCES	33
APPENDICES	
A. IRB Approval	35
B. Child Assent Form.....	36
C. Parental Permission Form	37
VITA.....	38

LIST OF TABLES

Table 1. A look at Gender in the Study	11
Table 2. Advanced Math Student Mathematical Demographics	12
Table 3. Types of assistance provided to both groups	17
Table 4. Pilot Trial 1 Daily Activities.....	20
Table 5. Pilot Trial 2 Daily Activities.....	21
Table 6. Experimental Trial 1 Daily Activities.....	23
Table 7. Experimental Trial 2 Daily Activities.....	23
Table 8. Group A Results Trial 1	24
Table 9. Group B Results Trial 1	24
Table 10. Group A Results Trial 2.....	25
Table 11. Group B Results Trial 2	25
Table 12. Raw Results	27
Table 13. Results Compensating for Group B's Greater Performance on Pretest 2.....	27

LIST OF FIGURES

Figure 1. Flowchart for Immediate Feedback.....	14
Figure 2. Screenshot of an incorrect sample Homework problem from MML	15
Figure 3. Screenshot of an incorrect sample Quiz problem from MML	16
Figure 4. Experimental Trial 1, Post-Test Scores	25
Figure 5. Experimental Trial 2, Pretest Scores	26
Figure 6. Experimental Trial 2, Post-Test Scores	26
Figure 7. Experimental Trial 2, Normalized Gain Scores (one outlier omitted)	27

ABSTRACT

Online homework is becoming a common type of assignment for math courses in secondary and post-secondary schools in the U.S. This study attempts to determine whether in this setting immediate feedback offers any advantage over delayed feedback in promoting learning gains in high school math. To this end, a study involving two comparable groups of students was performed, one group receiving immediate and the other delayed feedback. Both groups received their feedback in a computer-assisted environment. No significant difference in achievement between the two feedback groups was found.

CHAPTER 1

INTRODUCTION

MyMathLab (MML) is an online, interactive mathematical program provided by Pearson that can be personalized by the instructor to provide homework, quizzes, and tests on mathematical content. Students can access informative videos, animations and e-text and several other help features, such as “Help Me Solve This” and “View an Example,” both of which give step-by-step guides for current or similar problems. Educators and students seem to enjoy using the MML program. Since its release, more than 10 million students representing 2,000 institutions have learned mathematics using a MML product (Speckler, 2011).

In the educational setting, effective feedback typically is among the most powerful tools that teachers have (Hattie, 2008). One of the most helpful and popular features of MML is the availability of immediate feedback and the opportunity that students have to work a problem until it is correct. A few studies (Cutshall, Bland, & Mollick, 2012) and (Peterson, 2012) have looked at students’ positive perceptions of web-based assignments and conclude that immediate feedback (i.e., feedback supplied as soon as a student has responded to a question) is useful in the learning of the material. Others (Kulhavy & Anderson, 1972) (Sassenrath, 1975), and (Sturges, 1978) believe that delayed feedback (i.e., feedback withheld for a period of time after the student’s completion of an assignment) is more conducive to learning. More recently, Smith (2007) reviewed 39 different studies of feedback-timing effects on long-term retention. He found 16 studies that showed a significant advantage for delayed feedback, 12 that showed a significant advantage for immediate feedback, and 11 that failed to find any significant effect of feedback timing.

The implementations of MML that are presently being used seem to emphasize immediate feedback, while ignoring the possible benefits of delayed feedback. The present

study was designed to assess the differences in student learning from immediate versus delayed feedback in an MML class. This study provided immediate and delayed feedback to different groups using MML in an attempt to identify whether the timing of feedback had an effect on student learning.

The contents of this thesis are as follows. Chapter 2 reviews the literature on two topics: a) the value of computer-assisted learning and b) what is known about immediate and delayed feedback in education. Chapter 3 describes the location, student population and classroom environment involved in the experiment. Chapter 4 details the methods and procedures that the two pilot trials and the two experimental trials followed. Chapter 5 takes a look at the data, analyzing the information found. Chapter 6 concludes the paper, describing the inferences that can be made from the data and discussing implications.

CHAPTER 2

LITERATURE REVIEW

The review of literature begins with a brief discussion of online learning with attention to students' perceptions and then continues with a review of what is known about immediate versus delayed feedback and the effect upon student performance.

Articles in the literature review were collected from online databases such as JSTOR, EbscoHost and Google Scholar. The bibliographies of the sources identified in the initial search spawned a new collection-review cycle, gathering even more articles, and then a repeat of the process. Only peer-reviewed articles with empirical findings were included, and we focused on secondary and post-secondary education.

2.1 Discussion about Online Learning

In the past 20 years, many colleges and universities have implemented online homework systems in place of the traditional paper and pencil method. Most major college-algebra textbooks are currently accompanied by online homework systems such as MML (Brewer, 2009). The use of online homework systems in mathematics education has been the subject of much research (Brewer, 2009), (Mendicino, Razzaq, & Heffernan, 2009), (Kodippili, 2008), (Huang, 2008). Students have positive perceptions of computer-assisted learning (Cutshall et al., 2012), (Peterson, 2012), (Buzzetto-More & Ukoha, 2009), higher motivation to finish the homework assignments (Der Ching & Yi Fang, 2010), (Hodge, 2009), and they tend to perform better overall (Buzzetto-More & Ukoha, 2009; Kodippili, 2008).

Much research has shown that students respond well to computer-assisted instruction and online homework. Students seem to have the impression that MML is beneficial to their learning. Buzzetto-More and Ukoha (2009) collected survey data from 692 students enrolled in a remedial mathematics course at the University of Maryland Eastern Shore. Sixty-three (63)

percent of the students felt MML was a valuable learning tool, 56 percent felt the system helped them to learn concepts in the course, and 53 percent felt it helped them perform better on their assignments. Peterson (2012) collected pre- and post- surveys to track changes in perceptions of online homework. Based on open-ended responses to a post-survey, Peterson concluded that the “majority of students believed that online homework enhanced their understanding of the topics.” He also found that several students credited the instant feedback offered by the online software. The majority of students preferred online homework to traditional homework.

As well as having positive perceptions of computer-assisted learning, students seem to be motivated to complete more homework. Hodge, Richardson, and York (2009) investigated students’ motivation and perceptions while using a web-based homework tool. Survey data from about 1300 students enrolled in a college-algebra course indicated that they were motivated to complete more homework using the web-based tool than completing homework in the traditional paper-based manner. Additionally, one-third of the students felt the web-based homework improved their mathematical learning and understanding more than traditional homework methods.

It seems obvious that the more students are motivated to complete their homework correctly, the better they will perform in a course. In 2009, Buzetto-More and Ukoha compared longitudinal data collected for pass/fail percentages and course retention rates to examine changes occurring following implementation of MathXL (a program similar to MML) for homework assignments. The withdrawal rate for a remedial Math course decreased by 50 percent after the implementation of MathXL and the pass rates increased by 12 percent. Additionally, Kodippili and Senaratne (2008) studied the effects of online homework using MML compared to traditional pencil-and-paper based, instructor-graded homework. Their

study involved 72 students split between two instructors enrolled in a college algebra course at Fayetteville State University. Each instructor was assigned to teach two sections of MATH 123. Each instructor randomly selected one section to receive traditional paper-based homework, while the other section was assigned homework using MML. Students who worked on MML had a 70 percent success rate (i.e., a final grade of A, B, or C), while the success rate using the traditional pencil and paper method was 49 percent. Again, these results provide evidence that students seem to be more motivated to complete the course and perform better through the help of a computer-assisted learning environment.

Although computer-assisted learning is not the main focus for this thesis, it is important to examine the advantages that computer-assisted learning offers a mathematics student. Some researches imply the immediate feedback offered by the Web-based homework could be the reason for the success of computer-assisted learning environments (Cutshall et al., 2012; Peterson, 2012) (Hodge, 2009). Peterson (2012) states, “Students were able to correct misconceptions immediately by completing the online exercises while using the ancillaries.” Cutshall (2012) concludes, “the students thought that the web-based homework problems were useful and that the immediate feedback provided in the form of an explanation and a grade were useful in their understanding of the material.”

2.2 Immediate Feedback versus Delayed Feedback

MML, WebAssign, WeBWorK, and ALEKS are some of the most common computer-assisted learning tools, and all of them rely on immediate feedback. Immediate feedback has been defined as feedback that is supplied “right after a student has responded to an item or problem or, in the case of summative feedback, right after a quiz or test has been completed.”

Delayed feedback in contrast “may occur minutes, hours, weeks, or longer after the completion of some task or test” (Shute, 2008).

To compare immediate feedback with delayed feedback, some authors have compared online homework systems with traditional paper-and-pencil homework assignments. In 2009, Michael Mendicino, Leena Razzaq, and Neil Heffernan compared an online homework environment that provided immediate feedback in the form of hints and step-by-step scaffolding with traditional paper-and-pencil homework that was followed by a review of the problems the next day. The study followed 28 fifth grade students in four classes, two of which had online homework and two of which had traditional homework. The gain scores from the different groups were compared. The students with the online homework learned significantly more than the students who had the traditional paper-and-pencil assignment. The effect size was 0.61. (Mendicino et al., 2009).

A study completed at Brigham Young University in 2007 explored the effects of immediate versus delayed feedback for two non-cohort groups of high school students enrolled in distance-learning courses. At the time the study was conducted, BYU offered two types of distance learning, web-based and paper-based. Students in the web-based version of the course received immediate feedback and students in the paper-based version of the course received delayed feedback. The delay was dependent on the length of time it took to mail the assignment to the instructor and then wait for it to be graded and returned by the postal service. The students in the traditional course took a Scantron-based final and the web-based students completed their final in an electronic format. Students who received immediate feedback performed significantly better (as revealed by t-test) on the final exam. Those who received delayed feedback completed the course in significantly less time (Lemley, Sudweeks, Howell, Laws, & Sawyer, 2007).

In a highly cited article, Kulhavy and Anderson (1972) reviewed 11 teaching experiments comparing immediate and delayed feedback. Nine of these experiments provided evidence that delayed feedback was superior to immediate feedback. One possible explanation offered by these authors was the delay-retention effect, defined as the phenomenon that occurs when a “delay of reinforcement during acquisition facilitates retention of the learned material (Brackbill, Bravos, & Starr, 1962).” Kulhavy and Anderson suggest that there is a “greater preservation of errors when feedback is immediate than when it is delayed.” They conclude that feedback should be delayed for a day or two.

Another argument for delayed feedback is the spacing effect: the phenomenon whereby two presentations of material given with spacing between them generally lead to better retention than massed (back-to-back) presentations (Roediger & Butler, 2011).

Smith (2007) conducted a detailed literature review of 39 studies on feedback-timing effects on long-term retention. Of these 39 studies, 16 concluded that delayed feedback was better than immediate, 12 concluded that immediate was better than delayed, and 11 studies were inconclusive. Shute (2008) reviewed task-level feedback research within educational settings from elementary to post-secondary. She found five studies between 1969 and 1999 concerning immediate versus delayed and states, “there appears to be no consistent main effect of timing.” Azevedo and Bernard (1995) performed effect size calculations using 22 studies involving immediate feedback and found a weighted mean effect size of .80. From nine studies involving delayed feedback, a mean weighted effect size of .35 was obtained. Shute (2008) claims that this finding provides support for the strength of immediate feedback in computer-based environments.

In conclusion, the research to date on the timing of feedback is inconclusive with regard to the advantage that one form of feedback might have over the other. There appears to be no consistent main effect of timing. Note that no articles where delayed feedback was presented through the computer were found. The delayed studies were comparing computer-assisted assignments with paper-based assignments. The present thesis examines both immediate and delayed feedback all within a computer setting.

CHAPTER 3

THE STUDY

The purpose of this study was to investigate the differences between immediate feedback and delayed feedback provided in a MyMathLab environment. Although there have been many studies on the effectiveness of immediate feedback in computer assisted learning as opposed to delayed feedback on pencil-and-paper work, it is difficult to find research on the effects of delayed feedback within the computer-assisted environment itself. This study compares MML's built-in immediate, item-by-item feedback with feedback that was delayed until the end of the assignment.

3.1 Characteristics of the School

This study was done at the only high school in a small school district located in the state of Louisiana. The district had a total of four schools with a total of about 2,000 students from Pre-K to 12. The high school had a student population of about 600. About 60 percent of this population was Caucasian and about 40 percent was African-American. About 50 percent of the students received free or reduced lunch. Each class period consisted of 47 minutes, and the day was divided into eight class periods. The professional staff included one principal, three assistant principals, 53 faculty members, and several other staff.

3.2 Characteristics of the Mathematics Available at the School

In the state of Louisiana, students must complete four math courses with a grade of D or better to graduate from high school. Algebra 1 and Geometry are required. At the school where this study was completed, the other two courses could be chosen from the following: Math Essentials, Financial Math, Algebra 2, Advanced Math, Pre-Calculus, or Calculus. The students in this study were Juniors and Seniors enrolled in two sections of the Advanced Math course,

here referred to as “Group A” and “Group B.” Group A met in 3rd hour and Group B met in 4th. Both had the same teacher.

The Advanced Math class and the Pre-Calculus class were very similar courses designed for students who plan to attend a 4-year college. The Advanced Math course was a slower, less rigorous version of the Pre-Calculus course. Pre-Calculus was a dual enrollment course. For the 2012-2013 school year (the year before the study), this course was offered through the Early Start Program of Southeastern Louisiana University. These students had to meet the following requirements:

- be at least 15 years of age and currently in 11th or 12th grade
- be in good standing as defined by the high school
- be on track for completing the Louisiana Core 4 Curriculum
- have:
 - a) PLAN or ACT composite score of at least 18, and
 - b) PLAN or ACT mathematics sub-score of at least 19

Students in the Advanced Math class in this study had the option of taking a dual enrollment course was provided by Louisiana State University’s Early Start Program if they met the following requirements:

- have a composite ACT score of 22
- have a math sub-score of 19

Some students in this study took the Southeastern dual-enrollment course their junior year.

However, instead of advancing to the next level (Calculus), they decided to enroll in Advanced Math. By doing so, these students essentially chose to take a step backward and retake a more basic course. Some students in this study qualified for the LSU dual-enrollment course, but opted for Advanced Math.

Advanced Math is an abridged version of the dual-enrollment course. Advanced Math covers many of the same college algebra topics, but not at the same depth. Advanced Math also

has a much smaller focus on trigonometry. Trigonometry is still covered, but Advanced Math covers fewer objectives at a much slower pace, when compared with the Pre-Calculus class.

3.3 Subjects

The breakdown of the participants is shown in Table 1. A total of 39 high school students were included. There were 24 females and 15 males total. In Group A, there were 19 students (13 female and 6 male). In Group B, there were 20 students (11 female, and 9 male).

Table 1. A look at Gender in the Study

Gender	Group A	Group B
Female	13	11
Male	6	9
Total Students	19	20

The typical Advanced Math student has completed the following course offerings in the traditional order: Algebra 1 (9th grade), Geometry (10th), and Algebra 2 (11th). However, there are a few other variations. Although the majority of the students were seniors, there were four juniors included in the study. All variations of the students' past math courses are displayed in Table 2, along with the course background for both groups. The groups were alike in that they each had 13 students who took the traditional sequence of math courses. The groups appear to be relatively similar. The average ACT score for these two groups is a 20.33 with Group A averaging 20.05 and Group B averaging a 20.6 (a 0.55 difference). However, Group A differs from Group B by having a larger number of students who had taken Pre-Calculus. There were a total of 5 students who took the more rigorous dual-enrollment Pre-Calculus course as juniors

and decided to take Advanced Math as a senior. As explained previously, these students did not follow the natural progression of math instruction at the high school.

Table 2. Advanced Math Student Mathematical Demographics. Each row shows a possible progression of courses. The last column shows the student counts in each progression, and the average ACT scores for those students.

2009-2010	2010-2011	2011-2012	2012-2013	2013-2014 Advanced Math Students	Group A <hr/> Avg. ACT	Group B <hr/> Avg. ACT
7 th grade Mathematics (H)	Algebra 1	Geometry	Algebra 2	4 (All Juniors)	<hr/> 1 24	<hr/> 3 22
Algebra 1	Geometry	Algebra 2	Pre-Calculus 2-semesters of dual enrollment (LSU MATH 1021 & 1022)	3	<hr/> 2 26	<hr/> 1 25
Algebra 1	Geometry	Algebra 2	Pre-Calculus 1-semester dual enrollment (1021) and then skipped 1 semester of math	2	<hr/> 2 18.5	<hr/> 0 x
Algebra 1	Geometry	Algebra 2	Advanced Math	2	<hr/> 1 24	<hr/> 1 25
Algebra 1	Geometry	Algebra 2 (failed)	Algebra 2	1	<hr/> 0 x	<hr/> 1 27
Algebra 1	Geometry	Algebra 2	No math	1	<hr/> 0 x	<hr/> 1 27
8 th Grade Mathematics	Algebra 1	Geometry	Algebra 2	26	<hr/> 13 18.77	<hr/> 13 18.69
ACT (Math/March 2014) Average Per Group					20.05	20.6

3.4 Course

In the 2013-2014 school year, the Advanced Math course had the pre-requisite of completing the following courses with the grade of D or better: Algebra 1, Geometry, and Algebra 2 or Pre-Calculus. MML accounts were provided by the school district to insure that all students had access to MML. Topics covered in the course loosely followed the Louisiana State

University's MATH 1021 & 1022 course outlines. The e-text available through MML was Trigsted: Algebra and Trigonometry 1e (Copyright 2014 Pearson Education). The algebra course topics included linear equations, quadratic equations, linear inequalities, absolute value equations and inequalities, circles, lines, parallel and perpendicular lines, relations and functions properties of a function's graph, graphs of basic functions, composite functions, quadratic functions, exponential functions, logarithmic functions, and systems of equations. Trigonometry topics covered included an introduction to angles (degree and radian), applications of radian measure, right triangle trigonometry, trigonometric functions of general angles, the unit circle, the graphs of trigonometric functions, inverse trigonometric functions, law of sine and cosine, polar coordinates and polar equations, area of triangles and an introduction to vectors.

3.5 Research Design

The standard set-up for MML includes homework assignments, defined as a set of practice problems to prepare a student for a test or quiz. For every assigned homework problem, students are given three attempts to answer the problem correctly. After three failed attempts, MML uses the same algorithm that originally generated the problem to create a similar problem (2nd iteration). The student has another three chances to answer correctly. If the student still gets this problem wrong, MML uses the same algorithm to create a 3rd iteration of the problem with three attempts before it is finally marked incorrect. This is shown in Figure 1 below.

Besides giving immediate feedback on homework, MML responds in a specific way to incorrect solutions. Based on the error submitted, MML provides the student with a hint or an equation or formula in an attempt to help the student identify his/her error. Figure 2 illustrates this type of immediate feedback from a typical homework assignment within MML.

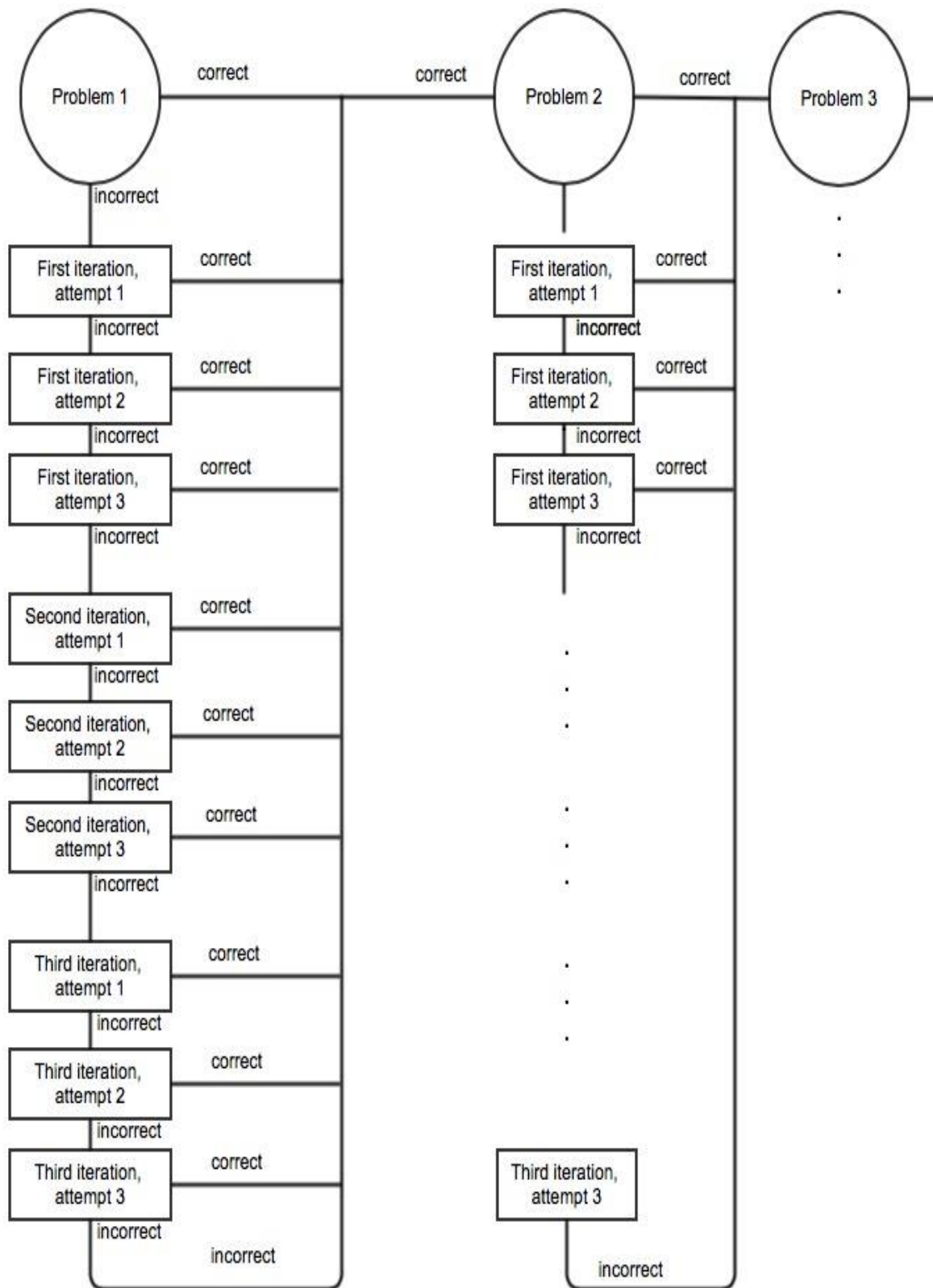


Figure 1. Flowchart for Immediate Feedback

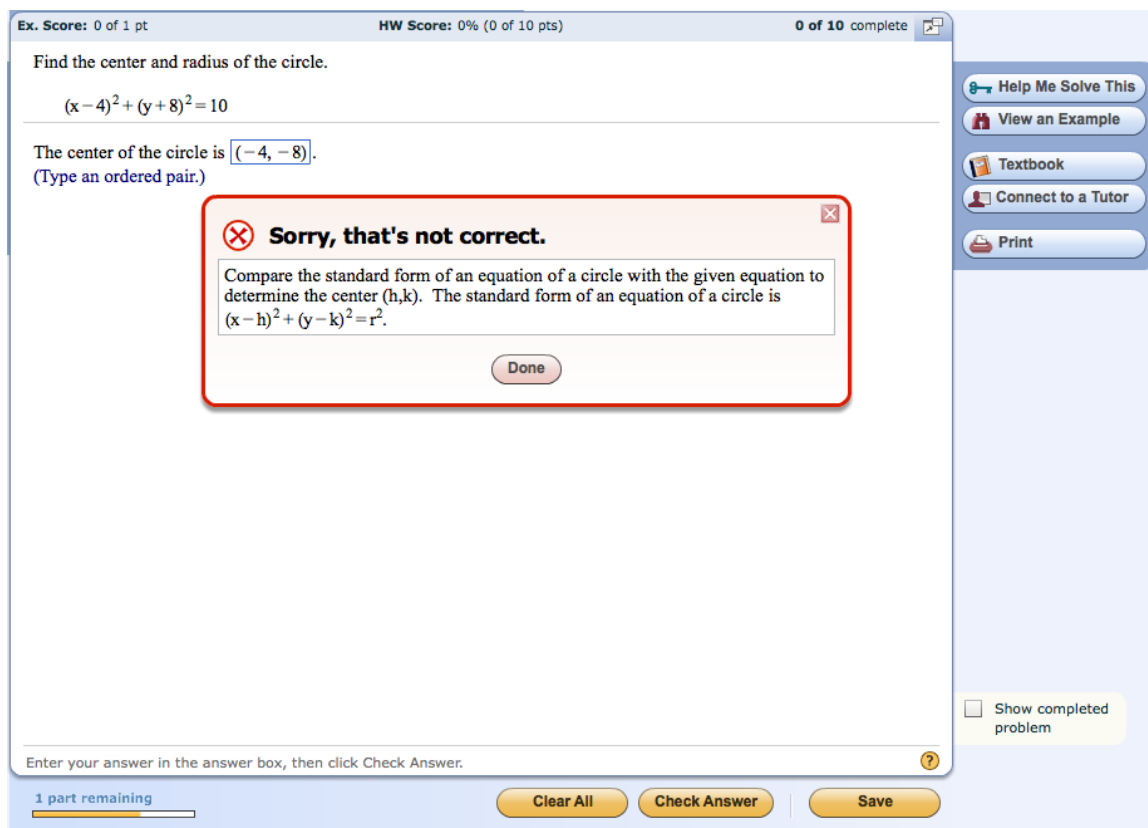


Figure 2. Screenshot of an incorrect sample Homework problem from MML. Problem from Trigsted: Algebra and Trigonometry 1e (Copyright 2011 Pearson Education).

Having described the mechanism for immediate feedback, we now describe the way that delayed feedback was provided. Because MML does not have an option to create homework assignments with delayed feedback, we created one. We did not give students any paper-based feedback. Delayed feedback was provided by using the “quiz” function in MML. Instructors can use the quiz function to create assignments with the same objectives as homework assignments and with all of the same assistance options (e.g., video, e-text, “View an Example” and “Help Me Solve This”), the only differences being that a quiz does not offer three attempts to get an answer correct and does not offer any iterations of the problem. Also, in quiz mode, MML gives no error-based responses other than “right” or “wrong.” No feedback was given to students until the entire quiz was submitted, at which time students were shown the correct

answers. Figure 3 shows the type of feedback the student would receive if a problem were incorrect. Notice that no hints are given for this type of assignment. If the solution was wrong, the student was shown the correct answer with a red triangle in the corner to indicate that the student's work was incorrect. If a student moved the cursor over the correct answer, he/she could view the answer submitted.

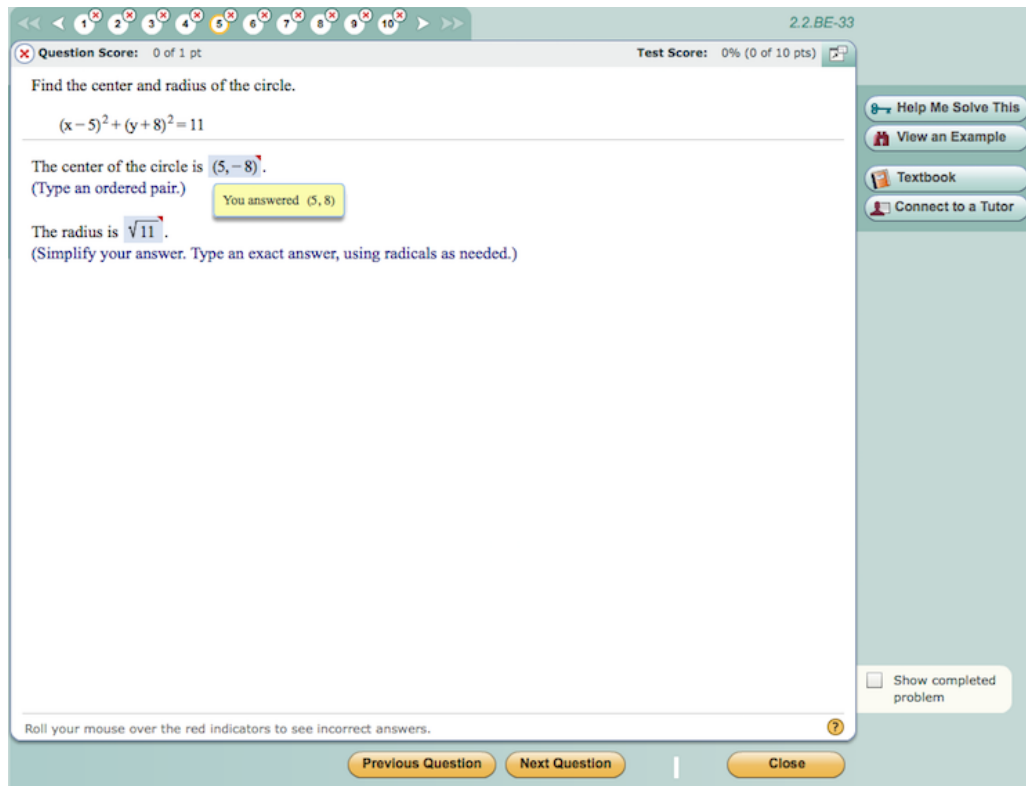


Figure 3. Screenshot of an incorrect sample Quiz problem from MML. Problem from Trigsted: Algebra and Trigonometry 1e (Copyright 2011 Pearson Education).

In each experimental trial, one of the two groups received immediate feedback and the other received delayed feedback. Both groups were required to turn in their work on paper. Table 3 shows how the two treatments were similar and different. The students in the “homework” group (immediate feedback) were allowed three tries to get a problem correct to earn a 100 percent on the assignment. The students in the “quiz” assignment (delayed feedback)

did not have the ability to correct their work online. In order to give both groups an equal opportunity to submit correct work for credit, students in the delayed feedback group (1) identified where they went wrong on their problem in writing, (2) explained their error, and (3) copied the View an Example. Copying the View an Example required the student to walk through the correct solution. All assignments in both groups were to be completed during class-time to avoid different learning opportunities for students with and without Internet access at home. Again, no paper feedback was given in this study. Students were only given feedback through MML.

Table 3. Types of assistance provided to both groups

Assistance Provided	Delayed Feedback “Quiz” type assignment	Immediate Feedback “Homework” type assignment
Immediate feedback		✓
Written Notes	✓	✓
“Help Me Solve This”	✓	✓
“View an Example”	✓	✓
Help from Classmates	✓	✓
Teacher Assistance	✓	✓

All students were allowed to use their notes, peers, teacher, internet searches, MML’s “Help Me Solve This,” MML’s “View an Example,” and were allowed to view the animations or videos that were available through MML. The study was designed to keep both groups as similar as possible to focus only on immediate versus delayed feedback.

3.6 Pre- and Posttests

A pretest was given to gauge prior knowledge, and a posttest was used to identify how much material had been learned. Pretests and posttests in the study were MML’s instructor-

made tests. Posttest results (or normalized learning gains, computed from pretests and posttests) were used to compare the immediate versus delayed feedback. The questions tested different levels of learning, though most were at the recall and comprehension levels.

For Experimental Trial 1, the posttest consisted of 10 questions with the following objectives: writing the standard form of an equation of a circle, sketching the graph of a circle, and converting the general form of a circle into standard form. The pretest was a subset of the posttest.

For Experiment Trial 2, the posttest consisted of 19 questions with the following objectives: understanding the definitions of relations and functions; determining whether equations represent functions; using function notation and evaluating functions; determining the intercepts of a function; determining the domain and range of a function from its graph; determining whether a function is increasing, decreasing, or constant; determining the relative maximum and relative minimum values of a function; and also determining whether a function is even, odd, or neither. The pretest was a subset of the posttest.

CHAPTER 4

METHOD

In this chapter, we describe how the data for the study was gathered. We begin with what took place prior to the study, then we describe two pilot trials conducted to test methods and procedures, and finally we describe the two experimental trials in which the data was collected.

By a “trial” we mean a single cluster of lessons spanning up to 7 days provided to both groups in the same time frame, with one group receiving immediate feedback and the other receiving delayed feedback. Trials were iterated, with the two forms of feedback alternating between the groups.

4.1 Prior to the Study

For two weeks, all 39 students in the study were taught basic trigonometry beginning with these topics: understanding degree measure, finding co-terminal angles using degree measure, understanding radian measure, converting between degree measure and radian measure, finding co-terminal angles using radian measure, classifying triangles, using the Pythagorean theorem, understanding similar triangles, understanding special right triangles, and using similar triangles to solve applied problem. Each student from each group was given the same two sets of assignments (the first had 37 problems, the second had 40 problems). The majority of the students had no prior experience with MML. The two large assignments gave the students a little bit of experience with MML, allowing them to get used to the format, the different features, and the precise way to input solutions. After the two-week warm-up period, the two groups were treated differently.

4.2 Pilots

In Pilot Trial 1, the purpose was not to collect data, but to determine the logistic feasibility. Both groups were given a class period to complete one in-class review assignment. Group A was given the delayed feedback while Group B was given the immediate feedback. This assignment had the same ten problems that the assessment would have and according to MML should have taken approximately 16 minutes to complete. After spending one class period working on these ten problems, the students spent the next class period with a review directed by the teacher. The very next day, the students in both groups were given an assessment based on the same ten problems. Table 4 provides an outline for the activities in Pilot Trial 1.

Table 4. Pilot Trial 1 Daily Activities

Pilot Trial 1	Day 1	Day 2	Day 3
Group A (delayed)	10 problems MML “quiz” Mode	Teacher Guided Review	Quiz with same 10 problems
Group B (immediate)	10 problems MML “homework” Mode	Teacher Guided Review	Quiz with same 10 problems

Both groups needed to become familiar with the MML program and with the purpose and design of this study. There were many complaints about the delayed feedback format (“quiz” mode in MML). Students complained that they did not get enough practice and that the “quiz” mode was more stressful than the “homework” mode. Students were hesitant about asking each other for help while “taking a quiz.” At first, students in the delayed group worried that their assignment grade would be what they made on the “quiz” assignment. Students needed reassurance that the term “quiz” was only an identifier for delayed feedback. Many students also did not complete the work required to support their grade by (1) identifying their error in writing, (2) correcting their error, and (3) copying a View an Example. It is unclear if students chose not

to do this, or if they did not understand that they could make up the grade by taking these steps. Many students also did not know how to access their quiz to review the correct answers with the incorrect answers they had submitted.

Pilot Trial 2 began with one day when both groups were given the exact same assignment with immediate feedback. Each assignment had the objective of understanding the definitions of the trigonometric functions. Starting on Day 2, Group A was given immediate feedback and Group B was given delayed—the opposite of Pilot Trial 1. The immediate feedback group was given twelve homework-type problems while the delayed feedback group was given eight quiz-type problems. The delayed group was given fewer problems with the intention of giving students more time to focus on finding the correct solution and to collaborate with their peers. (This is a difference of treatment, but as it occurred in the Pilot, no data was collected.) On day 3, the original intention was to give both groups a quiz (with all MML assistance features turned off). However, the delayed feedback group complained so much about not having enough practice and being unprepared for a quiz that on this third day, the delayed feedback group was given an additional day for practice. On day 4, the delayed feedback group members took a quiz to test their abilities. Table 5 displays the layout for the daily activities within Pilot Trial 2.

Table 5. Pilot Trial 2 Daily Activities

Pilot Trial 2	Day 1	Day 2	Day 3	Day 4
Group A (immediate)	8 problems MML “homework”	12 problems MML “homework”	QUIZ 6 problems	---
Group B (delayed)	8 problems MML “homework”	8 problems MML “quiz”	12 problems MML “quiz”	QUIZ 6 problems

After this pilot study, it was clear that both groups needed to be given the same amount of time and practice. It was also clear that the teacher needed a consistent identifiable method of instruction for each group, a method not affected by classroom teacher-student or student-student dynamics. Thus, the instructor modified instruction to include typed notes provided to the students to ensure that each class was getting the same teacher-guided notes.

4.3 Experiments

This was the first time data was collected for this study. Table 6 gives a picture of the activities performed. A pretest consisting of five questions was given before the trial was conducted. On Day 1, students were given a set of typed guided notes on the topic of equations of circles in standard form. The teacher lead the class, switching roles between demonstrating the steps and walking around the room directing the students as they worked, checking for understanding and answering questions as necessary.

On Day 2, the MML assignment of Circles in Standard Form was assigned. Group A was given the immediate feedback, while Group B was given the delayed feedback. The assignment consisted of 10 questions in which the students practiced writing the equation of circles in standard form.

On Day 3, the process was repeated with notes covering the objective of graphing circles with equations in standard form, and Day 4 was an MML assignment.

On Day 5, the teacher guided a review session. Day 6 concluded the experimental trial with a posttest of the material. The posttest was made with 10 questions (5 were the same questions given in the pretest).

For the second experimental trial, the groups alternated feedback types. A pretest consisting of six questions was given before the trial was conducted. Table 7 gives a picture of

the activities performed. On day 1, students were given a set of notes on the following topics: using function notation and evaluating functions; determining the intercepts of the graph of a function; determining the domain and range of a function from its graph; determining whether a function is increasing, decreasing or constant; determining relative maximum and relative minimum values of a function.

On day 2, each group was given its assignment on MML. Group B was assigned to immediate feedback, while Group A was assigned to delayed feedback. Each assignment had 20 questions.

On Day 3, the process was repeated with notes being supplied. Day 4 continued with a MML assignment. This assignment had 18 problems with the objective of sketching the graph of a basic function. On Day 5, students were given a Practice Quiz. On Day 6, the teacher reviewed the most-missed questions from the previous day's practice quiz, and Day 7 concluded with the posttest.

Table 6. Experimental Trial 1 Daily Activities

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Notes	MML	Notes	MML	Review	Posttest

Table 7. Experimental Trial 2 Daily Activities

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Notes	MML	Notes	MML	Practice Quiz	Review	Posttest

CHAPTER 5 DATA ANALYSIS

This chapter presents the pretest and posttest data as preparation for making comparisons between the two feedback types.

5.1 Data from Trial 1

The data from the Experimental Trial 1 is shown in Tables 8 and 9 with a graphical representation in Figure 4. Since the pretest showed essentially no prior knowledge, the posttests scores are equal to the normalized learning gains. Figure 4 shows no great differences between learning gains in the two groups ($p=0.4702$).

Table 8. Group A Results Trial 1

Student	Pretest	Posttest
1	0	70
2	0	75
3	0	52
4	0	31
5	0	16
6	0	54
7	0	37
8	0	10
9	0	72
10	0	16
11	0	100
12	4	73
13	0	43
14	0	60
15	0	40
16	0	58
17	0	38
18	0	15
19	0	100
Average:	0	51
StDev:	0	27.1

Table 9. Group B Results Trial 1

Student	Pretest	Posttest
1	0	75
2	0	28
3	0	50
4	4	90
5	0	90
6	4	63
7	0	28
8	4	41
9	4	46
10	0	33
11	0	72
12	0	100
13	0	66
14	0	67
15	0	96
16	0	2
17	4	61
18	0	34
19	4	58
20	0	35
Average:	1	57
StDev:	0	26.2

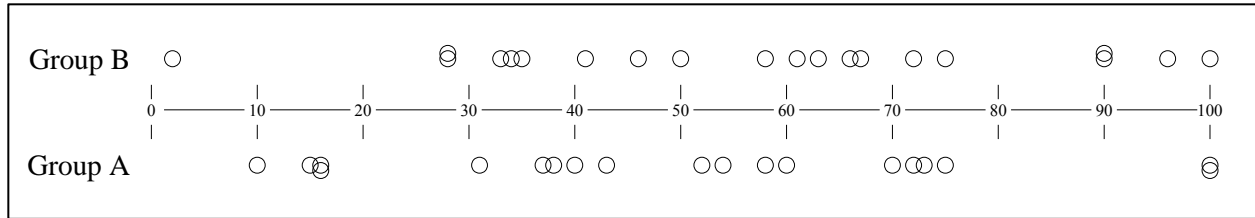


Figure 4. Experimental Trial 1, Post-Test Scores

5.2 Data from Trial 2

The data from the Experimental Trial 2 is shown in Tables 10 and 11.

Table 10. Group A Results Trial 2

Student	Pretest	Posttest	Normalized Gain
1	0	53	53
2	17	56	47
3	0	81	81
4	22	38	21
5	0	36	36
6	33	89	84
7	13	18	6
8	17	45	34
9	17	68	61
10	0	26	26
11	17	100	100
12	26	98	97
13	17	48	37
14	0	94	94
15	22	26	5
16	29	51	31
17	14	47	38
18	28	30	3
19	33	82	73
Average:	16	57	49
StDev:	12	27	32

Table 11. Group B Results Trial 2

Student	Pretest	Posttest	Normalized Gain
1	22	87	83
2	22	40	23
3	31	63	46
4	33	89	84
5	22	94	92
6	6	59	56
7	22	7	-19
8	22	69	60
9	39	44	8
10	28	92	89
11	22	85	81
12	42	100	100
13	22	74	67
14	17	95	94
15	35	89	83
16	22	49	35
17	0	3	3
18	17	84	81
19	25	40	20
20	33	38	7
Average:	24	65	54
StDev:	10	29	37

$\frac{(posttest-pretest)}{(100-pretest)})$ are used to gauge learning.

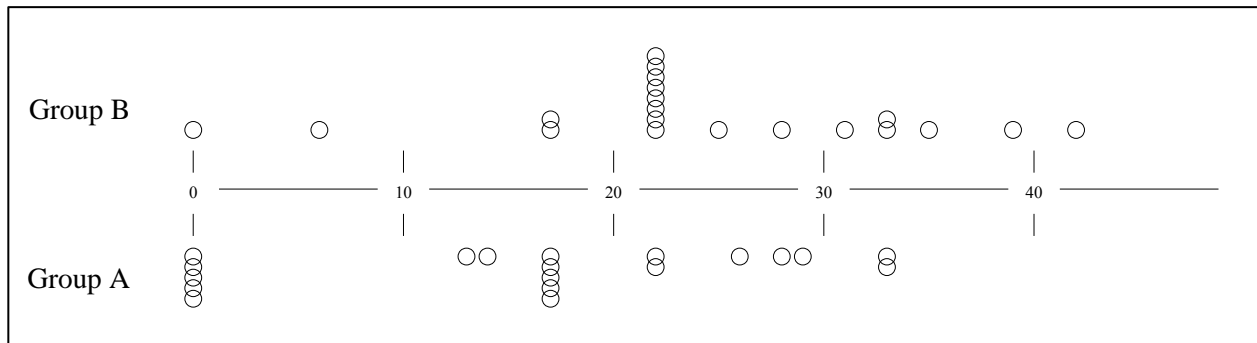


Figure 5. Experimental Trial 2, Pretest Scores

A by almost two-thirds of a standard deviation. In Figure 5, difference is evident. A t-test confirmed that the advantage of Group B on the pretest was significant ($p = 0.025$).

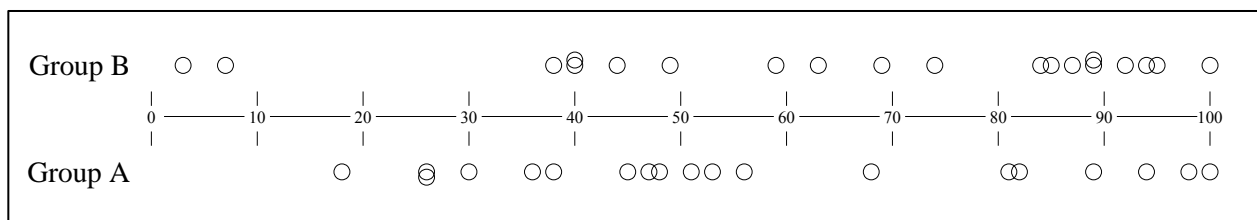


Figure 6. Experimental Trial 2, Post-Test Scores

perceptible, but it is not as great as on the pretest. A t-test shows that the difference is not significant ($p = 0.3817$).

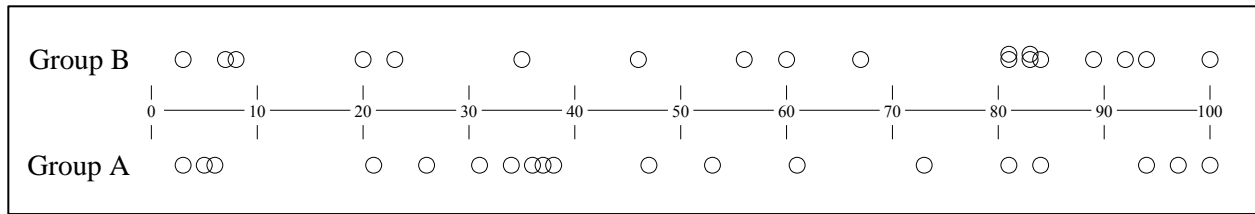


Figure 7. Experimental Trial 2, Normalized Gain Scores (one outlier omitted)

Figure 7 (above) shows the normalized gains of the two groups, omitting one outlier (a student whose posttest was lower than the pretest). Group B appears slightly stronger than Group A. However, a t-test shows that the difference is not significant ($p = 0.60$).

5.3 Final Results and Inferences

Table 12 shows the average posttest results from both experimental trials. Table 13 shows the average normalized gains. The figures are taken from Tables 8—11. The standard error of measurement of all numbers is about 6 percentage points. (Standard error is the standard deviation reported in Tables 8—11 divided by the square root of the number of students.)

Table 12. Raw Results

Posttest Averages		A	B
Experimental Trial 1	Immediate	51	
	Delayed		57
Experimental Trial 2	Immediate		65
	Delayed	57	
Average		54	61

Table 13. Results Compensating for Group B's Greater Performance on Pretest 2.

Normalized Gain Average		A	B
Experimental Trial 1	Immediate	51	
	Delayed		57
Experimental Trial 2	Immediate		54
	Delayed	49	
Average		54	57.5

CHAPTER 6

CONCLUSION

The purpose of this study was to investigate the effectiveness of immediate feedback versus delayed feedback provided by MyMathLab. Two experiments were completed in which each of the two groups were given the same classroom instruction but the in-class assignments had different feedback timing (immediate or delayed feedback). Pre- and posttests were given for both experiments. The first experimental trial lasted six days, while the second experimental trial lasted seven days. In this chapter, we discuss the findings, state the conclusions, and make some recommendations for future studies.

6.1 Discussion

At the beginning of this study, students were given detailed instructions on the forms of feedback they would be getting. Two pilot trials prepared the way for the experimental trials. Two experimental trials were conducted to collect data in order to compare the effects of immediate versus delayed feedback. The data was analyzed in Chapter 5. The goal was to find which form of feedback produced more learning.

Were the two groups similar enough to be used for the purpose of this experiment? In terms of mathematical background, ACT scores and the pretest results of Experimental Trial 1, the groups seemed to be well-matched. Nonetheless, on the second pretest, Group B had an advantage, beating Group A by almost two-thirds of a standard deviation of all scores on that pretest—a significant difference ($p = 0.025$). Group B also outperformed Group A on both posttests. Group B may have been composed of better students. Another possibility is that the class schedule favored Group B. So, in drawing conclusions, we need to bear in mind the possibility that Group B was inherently stronger, but this does not make it impossible to detect an advantage for one form of feedback, as we shall explain later.

What would we have seen if one form of feedback were preferable? We would expect to see greater learning gains in the group using that form, and we would use a t-test or other appropriate statistical test to determine if the observed difference was significant. However, if one group were composed of learners who were more effective for some reason other than the timing of the feedback, then we could mistake their learning gains for a benefit due to the feedback. This is the reason we alternated feedback. If one group had similar learning gains under both forms of feedback, this could suggest the feedback did not matter. However, if the excess gain of one group was much greater under one form of feedback than under the other, it would provide evidence to support the conclusion that this type of feedback was better. A mathematical representation for this is given below.

Let us introduce some symbols. Let A refer to the ability of Group A, measured in learning gains and let B refer to Group B. These are the learning gains that Groups A and B (respectively) would achieve without feedback. Let F_i refer to the added learning gains due to immediate feedback, and let F_d represent the contribution of delayed feedback. We are trying to decide whether or not we have evidence that $F_i > F_d$. We cannot deduce the values of F_i or F_d directly from the data.

Suppose we accept the idea that we can measure $A + F_i$ and similar net effects by using raw scores. Referring to Table 12, then, we have: $(A + F_i) = 51$, $(B + F_i) = 65$, $(A + F_d) = 57$, $(B + F_d) = 57$. Once we simplify the equations by solving for feedback, we have the following:

$$\begin{aligned} (A + F_i) + (B + F_i) &= 116 & (A + F_d) + (B + F_d) &= 114 \\ F_i &= 58 - \left(\frac{A + B}{2}\right) & F_d &= 57 - \left(\frac{A + B}{2}\right) \end{aligned}$$

Thus, the data in Table 12 suggests that F_i exceeds F_d by one percentage point.

Table 13 gives us the following information: $(A + F_i) = 51$, $(B + F_i) = 54$, $(A + F_d) = 49$, $(B + F_d) = 57$. Again, if we simplify the equation by solving for feedback, we see the following:

$$\begin{array}{ll} (A + F_i) + (B + F_i) = 105 & (A + F_d) + (B + F_d) = 106 \\ F_i = 52.5 - \left(\frac{A + B}{2}\right) & F_d = 53 - \left(\frac{A + B}{2}\right) \end{array}$$

Thus, the data in Table 13 suggests that F_d exceeds F_i by 0.5 of a percentage point.

By isolating the feedback, we can solve for the effectiveness of each form. But the advantages are very small. In fact (from Tables 8, 9, 10, and 11), the standard error of measurement of each of $A + F_i$, $B + F_i$, $A + F_d$ and $B + F_d$ is about 6 percentage points. (Standard error is standard deviations divided by the square root of N , and in each table the standard deviation is about 27 and the square root of N is about 4.5.) This means that we know the sums $(A + F_i) + (B + F_i)$ and $(A + F_d) + (B + F_d)$ with a standard error of about 8.5. This is a best error bound, discounting any non-random error. The differences in feedback are much less than the standard error, so we have not detected an advantage for one form of feedback.

The above analysis assumes that A and B have the same value in the two experimental trials—that is, A and B are not dependent on the material. From the pretest it was evident that students in neither group had any background knowledge of the standard form of an equation for a circle. However, for Experimental Trial 2, the pretest did show that students had some previous knowledge about relations and functions, and that Group B had significantly more. If the values of A and B actually did change between trials, this could conceivably have cancelled out the advantage of one form of feedback. Clearly, this is an issue that can only be addressed by further experimentation.

6.2 Recommendations

Students seemed to have contrasting confidence levels with the different assignments. Students seemed less confident with the delayed feedback and more comfortable with the immediate feedback exercise. Students might have been more complacent in the immediate feedback group because it was part of their normal classroom routine. If I were to do this study again, I would conduct the study throughout the entire year and make the alternating assignments the normal routine, instead of isolated events.

There are other factors that I could not control for. Students complained that the “quiz mode” (for the delayed feedback groups) was more stressful than the homework assignments. Although I reminded the students often that this was not an actual quiz, just the identifier for the assignment, students continued to complain. Students within the delayed group also felt that they did not get the same amount of practice because they only had to identify, correct and copy one similar problem. If they were part of the immediate feedback group, they could have up to nine attempts with a similar problem. If I were to do this again, I would try to find a way to compensate for this difference. By design of the experiment, it was important to keep both groups within the computer-assisted atmosphere and not introduce any written feedback. Additionally, the types of responses received by both the immediate and delayed groups were different. For the immediate feedback group, the students received helpful hints to examine incorrect answers whereas; the delayed feedback group only received the correct answer without hints. The delayed feedback group was reliant on analyzing their own work through class notes, a peer’s help, View an Example, or MML’s e-text, while the immediate feedback group received hints immediately.

Ultimately, this study did not find any differences between immediate and delayed feedback in the learning outcomes. It is known that under some circumstances, feedback can have a sizeable effect, so it is worthwhile to continue to seek ways to optimize the effect.

Because many of the students clearly do enjoy the immediate feedback from MML, I see no reason to avoid using it. Until better evidence is gathered, there is no reason to change current practices.

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APPENDIX A: IRB APPROVAL

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.



Institutional Review Board
Dr. Robert Mathews, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

– Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at <http://sites01.lsu.edu/wp/ored/human-subjects-screening-committee-members/>

– A Complete Application Includes All of the Following:

(A) A copy of this completed form and a copy of parts B thru F.

(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)

(C) Copies of all instruments to be used.

*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.

(D) The consent form that you will use in the study (see part 3 for more information.)

(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (<http://phrp.nihtraining.com/users/login.php>)

(F) IRB Security of Data Agreement: (<https://sites01.lsu.edu/wp/ored/files/2013/07/Security-of-Data-Agreement.pdf>)

1) Principal Investigator: Tamara Hebert

Rank: student

Dept: Natural Science, Mathematics

Ph: 225-301-5644

E-mail: tamarahebert3@gmail.com

2) Co Investigator(s): please include department, rank, phone and e-mail for each

*If student, please identify and name supervising professor in this space

Dr. James Madden

IRB# <u>E8416</u>	LSU Proposal # _____
<input checked="" type="checkbox"/>	Complete Application
<input checked="" type="checkbox"/>	Human Subjects Training
<input checked="" type="checkbox"/>	IRB Security of Data Agreement

3) Project Title:

Does the type of feedback on assignments affect student learning?

STUDY EXEMPTED BY:

Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
130 David Boyd Hall
225-578-8692 / www.lsu.edu/irb

Exemption Expires: 11/18/2016

4) Proposal? (yes or no) no

If Yes, LSU Proposal Number _____

Also, if YES, either

☒ This application completely matches the scope of work in the grant

OR

☐ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students)

11th and 12th grade high school students

*Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature

Tamara Hebert

Date

9/6/2013

(no per signatures)

** I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action:	Exempted <input checked="" type="checkbox"/>	Not Exempted _____	Category/Paragraph <u>1</u>
Signed Consent Waived?:	Yes <input checked="" type="checkbox"/> No		
Reviewer	<u>Mathews</u>	Signature	<u>Robert Mathews</u>
		Date	<u>11/19/13</u>

APPENDIX B: CHILD ASSENT FORM

Child Assent Form

I, _____, agree to be in a study to find ways to help teachers find more effective assignments that may help to educate children. I will be given MyMathLab assignments that will be formatted as a quiz instead of the normal homework format. I understand that I will be able to receive full credit for my assignments by identifying errors and copying the "Help Me Solve This" problems for the problems that I get wrong on the quiz-mode type assignments.

I can decide to stop being in the study at any time without getting in trouble.

Child's Signature: _____ Age: _____ Date: _____

Witness*: _____ Date: _____

* (N.B. Witness must be present for the assent process, not just the signature by the minor.)

STUDY EXEMPTED BY:

Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
130 David Boyd Hall
225-578-8692 / www.lsu.edu/irb

Exemption Expires: 11/18/2016

APPENDIX C: PARENTAL PERMISSION FORM

This is a parental permission form to participate in Mrs. Tamara Hebert's study, if needed.

Dear Parent,

Your child, _____, has been offered the opportunity to participate in a research study being conducted by Tamara Hebert for her masters' thesis assignment. The purpose of the study is to see if there are any differences in learning due to different feedback formats for MyMathLab assignments.

The study will occur in your child's advanced math classroom setting with Mrs. Tamara Hebert as the instructor. Students will be graded per the WFHS grading policies and will not be asked to do any extra work, physically or mentally harmful work, or receive any personal identification for participating in this study. The study will occur over the next school year and all participants will be given a pre/post test to measure content knowledge. For students choosing not to participate in the study, there will be no punitive grading or identification of their nonparticipation.

Should you have questions, concerns, or comments on the proposed study you may contact Mrs. Tamara Hebert at hebertt@wfpsb.org or (225) 635-4561 or the LSU graduate Advisor Dr. James Madden at madden@math.lsu.edu or (225) 578-7988. Thank you for your time and consideration.

Tamara Hebert

☐ I do give permission for my child to participate in the study.

☐ I do not give permission for my child to participate in the study

Guardian Name (Printed)

Guardian Signature

Date

Researcher (Tamara Hebert)

STUDY EXEMPTED BY:

Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
130 David Boyd Hall
225-578-8692 / www.lsu.edu/irb

Exemption Expires: 11/18/2016

VITA

Tamara Hebert was born in Oklahoma City, Oklahoma. She is married to Kerry Hebert and has two daughters, Annabelle and Carrie. She received a Bachelor's of Science in Electrical Engineering in December 2005 from the University of New Orleans. In 2007, Tamara accidentally stumbled into education as a career at Livonia High School. This new career path began by teaching 7th and 8th grade mathematics, but continued with Algebra 1, Algebra 2, Advanced Math, and Financial Math. After 5 years at Livonia High School, Tamara spent two years at West Feliciana High School teaching Advanced Math and is now looking forward to new experiences teaching mathematics at Catholic High School of Pointe Coupee.