Assessing the Emporium Model Through Student Performance and Persistence

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Abstract

The mathematics emporium model (MEM) was implemented to improve student success and retention rates. The college algebra course sequence was redesigned using the emporium model to establish consistency, emphasize active learning, modularize course materials, and provide one-on-one personalized on-demand assistance from faculty and teaching assistants. The emporium model ensured consistent content coverage and learning experiences, improved course coherence, and improved quality control. This study compared the course performance of students enrolled in a college algebra and trigonometry course using the MEM and traditional, lecture method. The results on whether the MEM or traditional students performed better were mixed. Also, the course effectiveness rates, which examines the successful performance of students enrolled in two successive courses that are associated such that the first course provides the foundation for the second, were similar for both the MEM and traditional methods.

Introduction

The report issued by the President's Council of Advisors on Science and Technology (2012) predicts that the workforce will experience a deficit of one million college graduates in science, technology, engineering and math (STEM) by 2022 and calls for addressing the shortfall by increasing the retention of college students in STEM (Graham et al., 2013). Therefore, this report provides a goal to which the nation should aspire: to increase the STEM college graduates by one million by the year 2022. In order to accomplish this goal, the report states that STEM graduation rates would have to increase by 34 percent. The most cited theories define student success in college as persistence and degree attainment, or achieving the desired educational credential (Xu, 2018; Kuh et al., 2006). However, on most campuses, the persistence and graduation rates of underrepresented minority (URM) and first-generation students still lag behind those of their majority counterparts (Elrod & Kezar, 2015). Therefore, to meet this goal, colleges and universities must address the success rate of URM and first-generation students.

Many students are not drawn to STEM majors because they are not motivated in the introductory courses (Seymour et al., 1997; Graham et al., 2013). To make these courses more appealing, many institutions have incorporated instructional methods that act to engage the student, known as active learning, which has been shown to improve student performance (Freeman et al., 2014) and reduce STEM attrition (Haak et al., 2011; Graham et al., 2013). Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert (Freeman et al., 2014) and includes any activity in which every student must think, create, or solve a problem. Active learning improves understanding and retention of concepts and information (PCAST, 2012). As Kuh et al. (2006) suggested, institutions need to invest in programs that support purposeful student and faculty contact, and active and collaborative learning, to provide institutional environments perceived by students as inclusive and affirming.

From a different perspective, institutional conditions are important to student success because it is unrealistic to hold only college students responsible for engaging themselves. Rather, faculty and administrators should foster the conditions that enable students to be engaged (Harper & Quaye, 2013; Xu 2018). "How to Engage" (2016) indicates that such things as a supportive network and outreach programs are things that can help more African American students participate in STEM.

To engage students in introductory mathematics classes, the mathematics emporium model (MEM) has been implemented at several universities with much success. This study examines the effectiveness of implementing the MEM strategy in a mathematics course sequence at a historically black college and university (HBCU). This study used data collected during Fall 2016 through Spring 2018 for sections of Math 101 and Math 102, a two-course sequence of college algebra and trigonometry. These sections used the MEM, an active learning methodology designed to foster student collaboration through group work (Teed & Slattery, 2011), which was implemented to improve student performance above the pre-emporium pass rates, which were in the 35%-40% range for Math 101 and 45%-49% range for Math 102. In this article, *effectiveness* means the *observed ability to accomplish intended purpose*: the attainment of passing grades in the course (course performance), and the performance in a second course that is directly dependent on the first course (dependent-course performance).

Problem Statement

This study investigates whether the measure of learning gains in college algebra is equivalent to that of course performance for the MEM and traditional instructional methods. The researchers compare two learning outcome measures: course performance and dependent-course performance, by addressing the following questions:

(1) Is there a significant difference in the course performance of the students in the MEM sections and those in the traditional sections?

(2) Is there a significant difference in the course effectiveness of the MEM sections and the traditional sections?

Review of Literature

There are many universities who have effectively redesigned their college level mathematics courses using active learning strategies with much success. Hagerty, Smith, and Goodwin (2010) provide a description of the algebra course redesign which incorporated whole class discussions, cooperative activities, relevant application problems, and fewer lectures which resulted in a 21% increase in passing rate, a 300% increase in enrollment in the subsequent math course and a 25% improvement in attendance.

Several universities have redesigned their math classes using the MEM strategy. The MEM eliminates lecture and uses interactive computer software combined with personalized, on-demand assistance (Twigg, 2011). Within a MEM environment, a student learns the concepts by working through the problems; therefore, the student is actively engaged. When the student does not understand or has a question, the student is able to obtain assistance by signaling to one of the teaching assistants. The idea behind the MEM is that you learn math by doing math (Twigg, 2011). Many MEM classrooms take the form of computer labs because each student is usually seated in front of a computer while working through problems. The method uses several teaching assistants circulating around the classroom to provide students assistance when they need it. There are several instructional tools which the method combines: computer assisted instruction and online work, peer tutoring, and active learning.

One of the features of the MEM is computer assisted instruction and online work. The results of using computer assisted instruction has been mixed. Kramarski and Hirsch (2003) studied a group of students and discovered that the students that used Computer Algebra Systems with Self-Regulated Learning outperformed those students that received Computer Algebra Systems without Self-Regulated Learning. Walker and Senger (2007) studied 120 African-American students and one white student and found no significant difference in achievement in developmental intermediate algebra students between the computer groups and the noncomputer groups. Gleason (2012) indicates that using technology in the form of online texts, homework, and tests can overcome the negative impact of large classes and that medium classes (30-55 students) had little to no benefit over large classes (110-130 students) in student learning and achievement with large classes having small to medium positive-effect sizes over medium classes in the area of student satisfaction.

The MEM incorporates learning activities designed to include peer and instructor discussion, which has been documented to increase interactive student engagement and learning (Hake, 1998). It also develops and encourages peer-facilitated learning, which has been shown to promote communication and cooperative learning among (Shechtman et al., 2010; Slavin, 2010). Robinson et al. (2005) found that peer tutoring in mathematics is a useful approach to improve the achievement level of African American and White students and those tutoring and those being tutored improved in academic achievement and experienced positive and attitudinal and socioemotional outcomes. However, DePree (1998) found that small group instructional methods did not improve achievements rates in algebra, but it did have a positive impact on course completion rates.

As the studies reveal, a course redesign of college algebra will not always ensure improved student performance and persistence. For instance, when Wynegar and Fenster (2009) compared the performance of students provided computer-aided instruction (CAI) to those in traditional lecture, they found that college algebra delivered through traditional lecture was associated with better final grades and lower failure rates. Their findings supported the findings of Stephens & Konvalina (1999) that students do not perform significantly better when CAI was used as an instructional method.

Course Effectiveness

The *course effectiveness* of a course examines the successful performance of students enrolled in two successive courses that are associated such that the first course provides the foundation for the second. We will say the first course is effective if students who are successful in the first course are sufficiently prepared to also be successful in the second course; *successful* for this purpose is defined as having earned a course grade of A, A-, B+, B, B-, or C. We define the *effectiveness rate* of the first course as the mathematical proportion of students that succeed in the second course after having successfully completing the first course, calculated with the formula:

$$Course\ 1\ effectiveness\ rate = \frac{Total\ A/B/C\ in\ Course\ 1\ enrolled\ in\ Course\ 2}{Total\ A/B/C\ in\ Course\ 2} x100$$

This report examines the course effectiveness of Math 101 with Math 102 as the second course.

METHOD

Participants

The participants in this study are all students who enrolled into the first and/or second semester of the Fundamentals of Algebra and Trigonometry I (Math 101-102) sequence in the Fall of 2016 and 2017 and Spring 2017 and 2018. The population profile in this study is similar to that in Cousins-Cooper et al. (2017).

Data and Measures

Data Collection: The post-test score and the course grade are the primary measures in the study to assess students' achievement. The instruments used to measure student success were tests administered at the beginning of the semester to measure initial mathematics knowledge and skills and at the end of the semester for all sections of college algebra. The tests were designed by a team of instructors that had years of experience teaching college algebra. In addition, this study used data provided by the University's Office of Institutional Research. The data that was provided by this office included gender, classification at the time of the course, and their current major, course grade, current GPA, high school GPA, SAT verbal score, SAT math score, and ACT score.

The control group consisted of nineteen sections of college algebra taught using the traditional lecture method. Students enrolled in the traditional, lecture sections of college algebra met with their instructor for three hours per week. For each traditional section, there was only one instructor and no GTAs assigned. The instructors for the traditional sections taught the same content and assigned the same homework as the emporium sections; however, each of these instructors developed their own tests and quizzes and employed their own grading standards.

The experimental group consisted of sixty-nine sections of college algebra taught using the emporium method. Students enrolled in the emporium instructional sections met four hours per week total. For three of these hours, students met in a classroom in which each student sat at a computer and worked through the class assignments. The emporium classroom, where course delivery occurred, is a computer lab with workstations. A workstation included a modular desk, a wheeled chair, and a networked computer for a student to work through online instructional modules. Each lab was equipped with thin-client terminals to facilitate students' interactive learning of course modules. Each class was staffed with an instructor and enough graduate teaching assistants (GTAs) to have a minimum ratio of one instructor or GTA for every twelve students.

During class time, students worked through their assignments and were able to ask the instructors and graduate teaching assistants (GTAs) questions about their work. To ask a question, the students would place a cup on top of the desk to signal to the instructors and GTAs that they had questions. Sometimes the instructors and GTAs were not able to get to a student immediately and during their wait time, students were encouraged to ask each other questions. The instructors and GTAs answered the students' questions on homework and tutorial questions, but not on tests and quizzes. For the fourth hour of the week, the students met with one of the GTAs in a regular classroom where the focus of this hour was on completion of additional practice problems from the course workbook. The GTAs were advised to allow the students to lead the process in solving the problem while the GTA facilitates the process.

Much effort was used to ensure that the MEM courses were all the same. The same assignments and same grading scale were used for each section. All the assignments for the MEM students were online except for the workbook assignments. The workbook was the only assignment that allowed the instructors to view a student's step-by-step procedure to solve the problems.

There were five modules for each college algebra course, developed by three math faculty members using Pearson's MyLabsPlus as a software platform for course delivery and management. Each course module consisted of a pre-test, instructional videos, workbook examples and exercises, homework problems, a quiz, a practice test, and a module test. To start a module in a course, a student was required to take the module pre-test to assess prior knowledge and mastery of the module content. If the student scored 85% or higher on the module pre-test, that student was allowed to proceed directly to the next module. Otherwise, the student was required to go through the module. Homework assignments within the module were generated based on the results of the pre-test.

Data Analysis: Dependent samples *t*-tests were calculated for fall 2016 and 2017 and for spring 2017 and 2018, to compare the mean pre-diagnostic scores to the mean post-diagnostic scores for MEM and traditional sections. To test the first hypothesis, two sets of analyses were performed: first, independent samples *t*-tests were calculated for fall, 2016 and for spring, 2017, to compare the final grades for MEM and traditional sections. Between-subjects factorial ANOVAs were also performed to compare final grades by gender. To test the second hypothesis, the *course effectiveness rates* of Math 101, with Math 102 as the second course, are calculated to compare the MEM with traditional sections, and female with male students. All samples *t*-tests were run to test hypotheses at the 95% confidence interval ($p<0.05$).

Results and Discussion

Table 1 and Table 2 summarize results showing that MEM improved mastery of defined learning outcomes more than the traditional sections for Math 101.

Table 1. Dependent t-tests for Math 101 Pretest and Posttest Scores by Course Type

Term	Type	Test	Mean	N	Std. Dev.	Std. Mean Error	T	p-value
FALL 16	Trad	Pretest	48.40	106	27.21	2.64	-8.12	0.00
		Posttest	70.11					
FALL 16	MEM	Pretest	39.93	556	27.47	1.16	-25.91	0.00
		Posttest	70.11					
SPRING 17	Trad	Pretest	43.57	71	27.36	3.25	-6.15	0.00
		Posttest	63.56					
SPRING 17	MEM	Pretest	31.70	248	33.35	2.12	-14.08	0.00
		Posttest	61.52					

As shown in Table 1, in both fall 2016 and spring 2017, a significant increase from pre- to post-test was found for both the MEM and the traditional course, the increase was 50% higher for the MEM sections.

Table 2. Dependent t-tests for Math 101 Pretest and Posttest Scores by Course Type

Term	Type	Test	Mean	N	Std. Dev.	Std. Mean Error	T	p-value
FALL 17	Trad	Pretest	44.68	181	21.80	1.62	-12.66	0.00
		Posttest	65.19					
FALL 17	MEM	Pretest	43.90	663	28.74	1.11	-22.34	0.00
		Posttest	68.84					
SPRING 18	Trad	Pretest	39.13	299	32.64	1.89	-9.67	0.00
		Posttest	57.38					
SPRING 18	MEM	Pretest	37.24	241	34.21	2.20	-9.10	0.00
		Posttest	57.29					

As shown in Table 2, in both fall 2017 and spring 2018, a significant increase from pre- to post-test was found for both the MEM and the traditional course, the increase was 50% higher for the MEM sections.

The final course grades of A, A-, B+, B-, B, C+, C-, C, D+, D, F, of students who enrolled in Math 101 were analyzed by type of course (e.g., emporium or traditional) and gender. An independent t-test was calculated to compare the final grades of students in MEM and traditional Math 101 courses. In fall 2016, the mean GPA of the traditional group was not significantly higher ($M = 2.54$, $SD = 1.07$) than the mean GPA of emporium group ($M=2.38$, $SD=1.25$), ($p > 0.05$). Table 3 depicts the findings. A between subjects factorial ANOVA indicated there was a significant difference in the final grades in Math 101 by gender when in emporium or traditional courses ($F(1,815) = 8.03$, $p < 0.05$). Male mean GPAs ($M = 2.63$) were higher than females mean GPAs ($M = 2.50$) in traditional courses. In contrast, females had higher mean GPAs ($M=2.53$) than male students ($M=2.10$) in emporium courses. In spring 2017, the mean GPA of the traditional group was significantly higher ($M = 2.49$, $SD = 1.06$) than the mean GPA of the emporium group ($M=1.94$, $SD=1.39$), ($p < 0.05$). Tables 3 illustrates the results. A between-subjects factorial ANOVA indicated there was a significant difference in the final grades in Math 101 by gender when in emporium or traditional courses ($F(1,354) = 9.85$, $p < 0.05$). Female GPAs ($M = 2.59$) were higher than male GPAs ($M = 2.32$) in the traditional courses. In emporium courses, mean female GPAs ($M=2.20$) were higher than mean male GPAs ($M = 1.47$).

Table 3. Fall 2016 & Spring 2017 Independent t-test Math 101 Final Grades by Course Type

Term	Type	Mean	N	Std. Dev	Std. Mean Error	T	p-value
FALL 16	Trad	2.54	237	1.07	0.07	-1.68	0.09
FALL 16	MEM	2.38	582	1.25	0.05		
SPRING 17	Trad	2.49	94	1.06	0.11	-3.44	0.00
SPRING 17	MEM	1.94	264	1.39	0.09		

In fall 2017, the mean GPA of the emporium group was not significantly higher (M = 2.32, SD = 1.22) than the mean GPA of traditional group (M=2.49, SD=1.27), ($p > 0.05$). Table 4 depicts the results. A between-subjects factorial ANOVA indicated there was not a significant difference in the final grades in Math 101 by gender or Pell grant status when in emporium or traditional courses ($F(1, 1027) = 1.37$, $p > 0.05$). The effect for type of course, emporium or traditional, was not significant ($F(1, 1027) = 1.44$, $p > 0.05$). The effect for Pell grant was not significant ($F(1, 1027) = 2.09$, $p > 0.05$. The effect for gender was significant ($F(1, 1027) = 17.10$, $p < 0.05$), females had higher mean GPAs than males, regardless of type of course and Pell grant status.

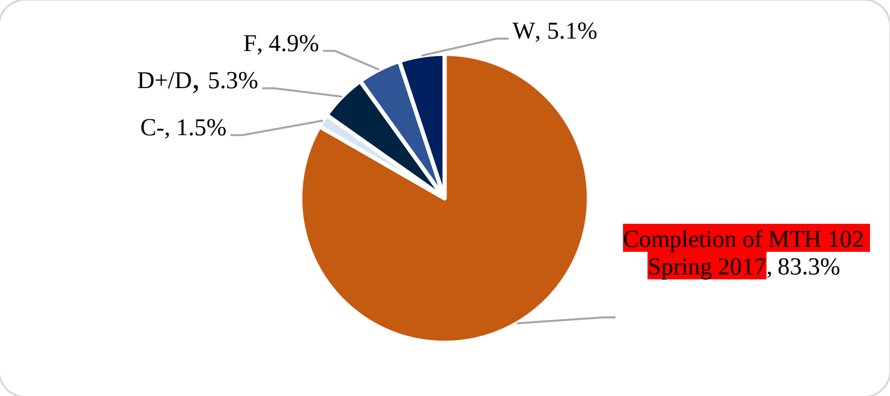
Table 4. Fall 2017 & Spring 2018 Independent t-test Math 101 Final Grades by Course Type

Term	Type	Mean	N	Std. Dev	Std. Mean Error	T	p-value
FALL 17	Trad	2.49	238	1.22	0.08	-1.81	0.07
FALL 17	MEM	2.32	797	1.27	0.04		
SPRING 18	Trad	2.38	104	1.29	0.13	-3.29	0.00
SPRING 18	MEM	1.88	282	1.33	0.07		

In spring 2018, the mean GPA of the traditional group was significantly higher (M = 2.38, SD = 1.29) than the mean GPA of emporium group (M = 1.88, SD=1.33), ($p < 0.05$). Table 4 depicts the results. A between-subjects factorial ANOVA indicated there was not a significant difference in the final grades in Math 101 by gender or Pell grant status when in emporium or traditional courses ($F(1, 377) = 0.91$, $p > 0.05$). The effect for type of course, emporium or traditional, was not significant ($F(1, 377) = 0.16$, $p > 0.05$). The effect for Pell grant was significant ($F(1, 377) = 7.1$, $p > 0.05$. Students who did not receive the Pell grant had a higher mean GPA (M = 2.42) compared to Pell grant recipients (M = 1.96). The effect for gender was not significant ($F(1, 377) = 2.90$, $p > 0.05$).

Chart 1 and Chart 2 summarize results showing that MEM resulted in higher persistence than in the pre-emporium traditional period. The course effectiveness analysis examines the successive courses of the Fundamentals of Algebra and Trigonometry sequence (Math 101 – Math 102). Charts 1 – 2 illustrates the findings.

Chart 1. Math 101 Course Effectiveness (Fall 2016-Spring 2017)

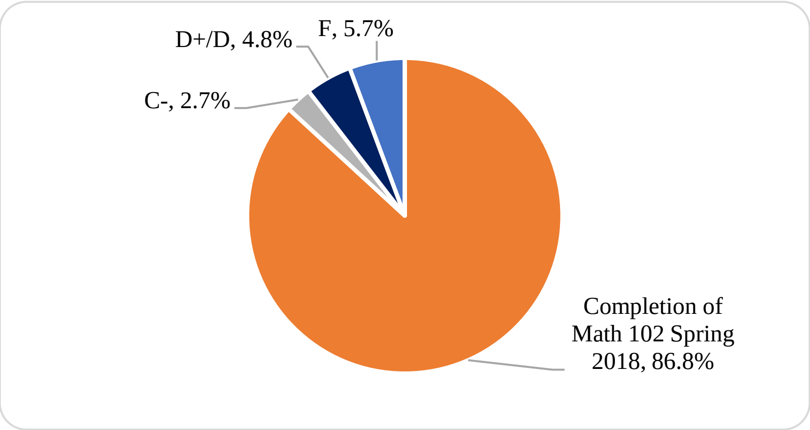


In the fall of 2016, 69.5% of students who were enrolled in MEM Math 101 were successful. From the students who were successful in Math 101, 72.9% (n=473) enrolled in Math 102. Those students who successfully completed Math 102, 83.3% (n=394), is the course effectiveness of the MEM.

Below are the findings for the course effectiveness for Fall 2016 to Spring 2017:

- 69.5% successfully completed Math 101.
- 72.9% of students who successfully completed Math 101 enrolled in Fundamentals of Algebra and Trigonometry II (Math 102).
- 83.3% of students successfully completed Math 102 (course effectiveness)
- MEM and traditional students had the same course effectiveness rate, 83.3%.
- Female students, 84.4%, had a higher course effectiveness rate than male students (77.0%).

Chart 2. Math 101 Course Effectiveness (Fall 2017-Spring 2018)



In the fall of 2017, 70.6% of students who were enrolled in the MEM Math 101 were successful. From the students who were successful in Math 101, 56.5% (n=334) enrolled in Math 102. Those students who successfully completed Math 102, 86.8% (n=290), is the course effectiveness of the MEM.

Below are the findings for the course effectiveness for Fall 2017 to Spring 2018:

Overall

- 69.0% successfully completed MATH 101
- 63.1% of students who successfully completed MATH 101 enrolled in MATH 102
- 86.5% of students successfully completed MATH 102 (course effectiveness)

MEM

- 70.6% successfully completed MATH 101
- 56.5% of students who successfully completed MATH 101 enrolled in MATH 102
- 86.8% of students successfully completed MATH 102 (course effectiveness)

Traditional

- 73.9% successfully completed MATH 101
- 66.8% of students who successfully completed MATH 101 enrolled in MATH 102
- 82.1% of students successfully completed MATH 102 (course effectiveness)

Conclusion

The MEM provides students with an environment for engaged student learning and increases overall math proficiency in the college algebra and trigonometry courses. The MEM known for students' interactive personalized learning with computer aid and on-site assistance, combines several instructional components such as cooperative learning, online instruction, computer-assisted instruction, and immediate feedback from instructors. In the MEM, the role of the faculty moves from one of distributor of information to one of helper in the learning process. The MEM requires the students to become actively engaged in learning the course material.

This study examined the effects of implementing the MEM in a college algebra and trigonometry course over a period of four semesters on the performance of students and the results were mixed. For each semester, a significant increase from pre- to post-test was found for both the MEM and the traditional course, and the increase was 50% higher for the MEM sections. However, when analyzing the final course grades, the Spring 2017 and 2018 semesters showed that the traditional group significantly outperformed the MEM group. In the Fall 2016 and 2017 semesters, there was no significant difference in the final course grades between the MEM and the traditional groups. These mixed results suggest that further study is needed to investigate whether students enrolled in the MEM or traditional group perform better or whether there are other factors affecting students' course performance.

Also, this study examined the course effectiveness rates of the MEM as compared to the traditional. The *course effectiveness* of a course examines the successful performance of students enrolled in two successive courses that are associated such that the first course provides the foundation for the second. In this study, the first course was MATH 101 and the subsequent course was MATH 102. The results indicate that the course effectiveness rates for the MEM and the traditional, lecture sections were similar.

The current study should be expanded to include more college and university settings that offer both the MEM and traditional instructional formats for math courses. For future research, the study should be replicated with a larger sample size to determine if significant differences exist between the two class formats.

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