Emporium Model: The Key to Content Retention in Secondary Math Courses

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Abstract

The math emporium model was first developed by Virginia Tech in 1999. In the emporium model students use computer-based learning resources, engage in active learning, and work toward mastery of concepts. This approach to teaching and learning mathematics was piloted in a rural STEM high school. The purpose of this experimental study was to compare the impact of the emporium model and the traditional approach to instruction on student achievement and retention of algebra. The results indicated that both approaches to instruction were equally effective in improving student mathematics knowledge. However, the findings revealed that the students in the emporium section had significantly higher retention of the content knowledge.

Keywords: Emporium model, content retention, online learning, mastery learning, secondary education

INTRODUCTION

Recent adoption of the Common Core State Standards (CCSS), along with calls for implementation of non-traditional, inquiry-based approaches to instruction, and evaluation of current formative and summative assessment practices are just some of the numerous outcomes of the K-12 educational community's initiative to merge teaching and learning into one strong entity. This effort is especially critical in mathematics, a discipline which constructivist nature demands a true comprehension of one concept before moving on to the next one. Unfortunately, in most mathematics classrooms around the nation, assessments that supposedly address this comprehension of knowledge are mainly evaluative in nature. They only determine if a student has learned and do not impact the subsequent process of teaching and learning for that student. The class, led by its teacher, moves on to the next topic, the one that most likely is built on the concepts that the student did not master. It is relatively easy to predict what happens to any student who gets caught in this seemingly well-oiled machine called "education", where knowledge and retention of content are needed, but may not be effectively empowered.

LITERATURE REVIEW

Mastery Learning

The concept of mastery learning is not unique to the 21st century. As a matter of fact, there are reports of students being required to exhibit mastery of material before moving on in their studies dating back to 1920s and 1930s (Kulik, Kulik, & Bangert-Browns, 1990). In their meta-analysis, Kulik et al. (1990) synthesized the findings of approximately 100 research studies that demonstrated positive impact of mastery learning on student academic performance and retention of the learned content across various disciplines and grade levels. All of the reviewed studies employed one of the two most prominent teaching methodologies that embraced the mastery component of learning: Bloom's Learning for Mastery (LFM) and Keller's Personalized System of Instruction (PSI).

Both methodologies are based on the notion that the mastery approach contributes to reducing variation in student performance by increasing variation in teaching (Guskey, 2007). More specifically, Bloom approaches in-class assessments as formative learning tools that modify and guide the instruction. These tools are often different based on individual student needs. The assessments are no longer designed to be part of an evaluative process that aims to determine, but not improve student current knowledge (Bloom, 1968; Bloom, 1971; Guskey, 2007). In classrooms that adopt Bloom's learning for mastery model (often called mastery learning) the material is presented by teachers, and students move through the course at a pre-determined pace. After the formative assessment is administered and analyzed, the students who master the material (typically, the mastery level is at least 70%) are provided enrichment opportunities, while the others remediate through teacher-designed correctives. The correctives are individualized activities that help students improve their comprehension of the material. Successful completion of the correctives is followed by a re-assessment, which is another chance for students to demonstrate their mastery. Only after the re-assessment is administered, the entire class advances to the next unit (Bloom, 1968; Bloom, 1971; Guskey & Jung, 2011).

In classrooms that adopt Keller's Personalized System of Instruction (Keller, 1968), the material is presented to students in an alternative way, without teacher's lectures or class discussions. The students may watch videos, use online learning software, or read textbooks. This format allows students to move through the material at a pace suited to their own abilities. It also enables students to reach mastery at different times throughout the school year independent of their peers' progress. The teacher's role in classrooms that adopt this model resembles the role of a coach or a tutor, a support person who provides individualized instruction only when needed. Very often, especially in higher education, teacher-student communications in PSI based courses are conducted primarily through written feedback (Keller, 1968). The format of the PSI model is especially attractive to distance learning and online education, or schools that incorporate technology in their classrooms, because it allows instruction to shift to a digital, asynchronous teaching and learning environment (Eyre, 2007).

The Emporium Model

Mastery learning is a critical component of the emporium model. The math emporium model was first developed by Virginia Tech in 1999 as a part of the Program in Course Redesign. The main objective of this program was to redesign higher education instruction to use technology in improving quality of student learning, as well as decrease cost of instruction (Twigg, 2003). Virginia Tech was one of 30 colleges and universities that were supported in their course redesign efforts by an $8.8 million grant from the Pew Charitable Trust managed by the National Center for Academic Transformation (NCAT) at Rensselaer Polytechnic Institute (Twigg, 2003).

In the emporium model students use computer-based learning resources, engage in active learning, work toward mastery of concepts, and receive help from their instructor when needed (Twigg, 2003; Twigg, 2011). This teaching method successfully addresses several shortcomings of traditional instructional approaches. The lecture method does not differentiate between students. It does not acknowledge, nor accommodate the fact that students may have different academic needs and abilities, as well as learning styles (Twigg, 2004). More specifically, students with weaker skills may need additional support, especially when their prior knowledge is concerned. These students also often struggle with the pre-determined pace of the class. On the other hand, students with stronger mathematics skills may have potential to move at a faster rate and focus only on the material they have not yet learned. Unfortunately, locked in the pace of the entire class, these students are at risk of becoming less motivated and engaged, which in turn may negatively affect their performance. Therefore, the shift from a traditional, often didactic teaching approach to the emporium model would allow students to move "from a passive learning environment to an active one in which the student controls and individualizes the learning" (Twigg, 2004, p.151).

Emporium Model in High School

The mathematics courses that benefit the most from redesign to include technology are those that have high failing rates or those that historically have students with inconsistent preparation levels (Bonham & Boylan, 2011). Although originally developed for higher education, the rationale behind the emporium model can be easily applied to secondary mathematics education. This approach to teaching mathematics was piloted in a rural STEM high school during the 2014-2015 academic year. As a public high school, this STEM focused institution accepts any incoming freshmen residing in the state. High schools that have the STEM designation are still fairly rare and students from numerous neighboring counties apply in large number. Due to the school's limited student population capacity, only 100 freshmen are accepted each year (through a lottery based selection) to ensure that the overall student population of the school does not exceed 400 students.

At the time of the study, the school was in its third year of existence and had approximately 240 students (the current sophomore, and particularly the inaugural junior class, were smaller in size). The students in this school come from 37 different school districts and 6 counties. The number of female and male students is relatively comparable (52% and 48%, respectively). The school has a low percentage of minority students (approximately 3%), which closely resembles the demographics of the rural communities from which the majority of students come. The current percentage of student body that receives free/reduced lunch is approximately 10%. Similar to other STEM schools, this institution is one-to-one, meaning that every student has a personal laptop computer they use in their classes and for work at home (for details on one-to-one computing, please see Grimes & Warschauer, 2008).

In addition to embracing non-traditional teaching methods and integration of curricula across all disciplines, this school has also adopted the mastery for learning model (Bloom, 1968; Bloom, 1971). The school has developed student success plans for all grades, and while the plans vary slightly for different levels of students (freshman, sophomore, junior, and eventually senior), they are all based on Bloom's mastery learning principles. However, the benefits of mastery learning come with certain challenges, such as identifying appropriate remediation methods and allotting necessary class time for their implementation. This challenge is very prominent in mathematics, especially in entry level courses, such as the introductory algebra course offered at the freshman level in this school. The content standards of this particular course align with the Algebra I Common Core State Standards in Mathematics (Mathematics Standards, 2014), and for the purpose of this study, this course will be referred to as Algebra I.

All incoming freshmen are administered an achievement test in mathematics that encompasses all topics covered in an Algebra I course. Students who score 70% or higher on the test are enrolled in Algebra II, while everyone else is placed in Algebra I. The students enrolled in the school come from many different middle schools (from approximately 37 school districts and 6 counties) and their corresponding eighth grade math classes vary significantly in both content and rigor. This is reflected in an alarmingly large range of mathematical abilities and prior content knowledge for the students in the Algebra I class. Designing traditional, face-to-face lessons that are suitable for all students enrolled in such a course is very challenging, if not impossible. Very often, the lessons end up targeting the “middle-achieving” students, resulting in only a small group of students who truly benefit from the instruction and whose knowledge of mathematics is positively impacted. Lower-achieving students struggle with the pace of a teacher-led class and often need additional, preferably one-on-one assistance. High-achieving students may not feel academically challenged, their motivation levels decrease, and they may become disengaged from the class. This, in turn, could negatively affect their math performance and overall achievement. Taking into account that the emporium model appears to be best suited for students with a wide range of mathematical abilities and different learning rates (Twigg, 2003), the adaptation of this teaching model seemed highly appropriate for the Algebra I course offered in this school.

METHOD

Purpose

The purpose of this study was to compare the impact of the emporium model and the traditional approach to instruction on student academic achievement and retention of knowledge in Algebra I. Although the traditional format of teaching is often viewed to be primarily didactic in nature, in the STEM school where this study was conducted the label of traditional teaching was simply used to distinguish from the emporium model. More specifically, lectures in the traditional classrooms were frequently supplemented by inquiry-based lessons, guided questioning, and project-based learning activities.

The main research question this study aimed to answer was the following: 1) Do students taught using emporium model perform higher on Algebra I achievement tests than their counterparts who are taught using traditional methods? Keeping in mind the constructivist nature of mathematics, this study also examined the knowledge retention of traditionally taught students and those enrolled in the emporium model section of the same course. The research question guiding this inquiry was 2) Do students taught using the emporium model have higher knowledge retention levels of the material than their counterparts who are taught using traditional methods?

In this paper we describe the study and its participants, methods of data collection, analyses of data after the first part of the school year, and finally the results of those analyses and their implications.

Sample

This study employed the experimental, parallel sections research design. Sixty two freshmen students who scored below 70% on the achievement test were enrolled in the Algebra I course. Prior to the beginning of the school year these students were randomly placed in either the experimental section or the control section. The experimental section had 30 students (16 female and 14 male) and the control section had 32 students (14 female and 18 male). Both sections of the course had the same teacher. While in the control section, the teacher employed a traditional method of instruction that consisted of face-to-face lectures, class discussions, problem-solving activities, and occasional inquiry-based lessons. While student participation and group work were highly encouraged, and often incorporated into class lessons, the main learning resource for the students in the control section was the teacher. The teacher followed a pre-determined pacing guide and all students, under her guidance, progressed through the material at the same rate.

The material covered in this course was divided into meaningful content units. After each unit was completed, the class was given a summative assessment that was designed to evaluate student comprehension of the targeted content standards. The assessment was given as a paper-pencil test consisting of questions presented in open-ended format. Students who scored below 80% on the summative assessment had an opportunity to remediate and reassess on the material.

The students in the experimental section used online learning software Assessment and Learning in Knowledge Spaces, ALEKS, to help them learn the mathematics content. ALEKS is a web-based learning system that uses artificial intelligence to provide an individualized learning experience for each student. Through adaptive questioning, ALEKS determines what the student does not know and then provides instruction on the topics the student is ready to learn (ALEKS, 2014). The crucial feature of ALEKS, especially for schools and courses that have adopted the mastery for learning model, is periodic reassessment to ensure that the learned topics are retained.

The role of the teacher in the emporium section did not include providing daily overview of the material, nor addressing questions with the entire class. Instead, the teacher offered individualized assistance to students who struggled with certain concepts or had questions. To indicate that they had a question during a class, students would place a plastic cup on their desk and wait for the teacher to be available to help. The students were encouraged to work collaboratively and use textbook or online resources to help them overcome their obstacles.

The first time the students in the emporium section logged into their ALEKS accounts they were given a placement test. The purpose of the placement test (designed by ALEKS) was to determine each student’s current mastery level of course topics and to identify learning gaps.

Therefore, students had different starting points (as shown in Figure 1) and learning paths through the course in order to fill those gaps. Engaging in their personalized online learning environments enabled the students to work on the material at their own pace.

However, individualized student learning paths also meant that the students would be completing the content units at different rates, so administering summative assessments to the entire class on the same day would not be feasible. Instead, each student was administered assessments once they mastered the corresponding content topics in ALEKS. These assessments were given through ALEKS, but they aligned in content to the assessments given in the control section. The students in the emporium section who did not score at least 80% on the summative assessment had to reassess on the material after they were given time to remediate, same as their counterparts in the traditional format section of the course.

Data Collection

The STEM school in which the study took place is a year-round institution. The school year consists of three regular terms and two accelerated terms. During the three academic terms the students enroll in the standard high school curricula courses (mathematics, science, language arts, etc.). During the accelerated terms (which are typically two-three weeks in duration), students attend elective courses (such as bridge building, robotics, programming, creative writing, cryptology, to name just a few), but take no regular courses. The first term of the academic year is typically 15 weeks long, and lasts from August to November. The first accelerated term follows term 1 and precedes the three-week long winter break. The second term, which starts after the winter break, is approximately 12 weeks long and ends in March. The second accelerated term and the spring break last about five weeks total and end in April. The school year concludes with term 3 which lasts from April to June.

Mathematics knowledge of all students enrolled in the Algebra I course was measured by an achievement test. In order to determine the students' prior knowledge of Algebra I concepts, the achievement test was administered at the beginning of the school year. The students took this test again during the last week of the first term and on the first day of the second term. The achievement tests were administered during the regular class periods, and each time the students were given 60 minutes to complete the test.

The achievement tests were independently graded by two high school mathematics teachers. The questions on the achievement test scored '1' if they were correctly answered or '0' if the answer was incorrect. No partial credit was given during the grading process. In cases where the final scores given by the two teachers were different, the graders discussed the question and its answer until a consensus on the score was reached.

Instrument

The achievement test used to measure students' knowledge of Algebra I concepts consisted of forty open-ended questions. The test was organized into three main parts (term 1, term 2, and term 3 topics) that corresponded to the school term during which the topics addressed were to be taught in the control section. Term 1-topics included Solving Linear and Absolute Value Equations and Solving Linear and Absolute Value Inequalities. Introduction to Linear Functions, Systems of Equations and Inequalities, and Exponents and Exponential Functions were included in Term 2-topics. Finally, Term 3-topics consisted of Quadratic Functions and Equations, Polynomials and Factoring, and Radical Exponents and Equations. The items on the test, which aligned with the CCSS for Algebra I (Algebra I Standards, 2015), were developed collaboratively by a high school mathematics teacher who has adopted and implemented the CCSS in her classes and a professor of mathematics from a local University who has been involved in development of curricula and assessment for mathematics.

To establish the content evidence of the achievement test, three additional mathematics educators were asked to serve as jurors in validating the assessment. All individuals were experts in mathematics and education, and have demonstrated knowledge in both fields (holding a graduate degree in mathematics or mathematics education). It was agreed that the achievement test adequately assessed the main learning outcomes targeted by the objectives of an Algebra I course as mandated by the CCSS in mathematics. Additionally, five students (not participating in the study) were asked to read the questions for clarity. No changes were made to the achievement test as a result of these reviews.

In order to determine the reliability of the achievement test, the test-retest reliability was examined. The test-retest reliability addressed the level of confidence one has in the scores produced by the test, which need to remain the same when measured on two different occasions. In this particular case, the retest was given three weeks after the test under the same conditions to a population not participating in the study nor enrolled in an algebra based course. The test-retest reliability coefficient was .94. To further examine the reliability, coefficient alpha was computed and found to be .82, confirming that the consistency of the scores on the achievement test over time was very high.

Results

At the beginning of the school year the students were randomly placed either in the emporium model (experimental) section or the traditional format (control) section of the Algebra I course. To ensure that the groups were comparable in their prior mathematics knowledge, their average scores on the achievement test given at the beginning of term 1 were compared. The emporium section had slightly higher average scores on the achievement test ($M = 10.62, SE = 1.78$) than the control group ($M = 10.47, SE = 1.38$). This difference was non-significant ($t(60) = .069, p > .05$) and it represented a very small-sized effect, $r = .01$.

The achievement test was given to all students again at the end of term 1 (that lasted 15 weeks), and their average scores were compared across the sections. The average scores of the emporium section ($M = 21.03, SE = 3.06$) were not significantly different than the average scores of the control section ($M = 21.08, SE = 1.82$), $t(47.612) = -.014, p > .05$, $r = .002$.

In addition to comparing the average scores on the achievement test after the first term, the student learning growth during this period was examined for both groups. The student learning growth was measured by the difference between the students' scores on attempt 2 (given at the end of term 1) and the students' scores on attempt 1 (given at the beginning of term 1) of the achievement test. Although the emporium section had higher average scores on the achievement test than the control group, the students in the control group had a larger average learning growth. However, the difference between the average learning growth in the control section ($M = 11.48, SE = 1.41$) and the emporium section ($M = 9.97, SE = 1.75$) was non-significant ($t(60) = -.679,\ p > .05$), and it represented a small-sized effect, $r = .09$.

Both groups of students demonstrated a notable learning growth in algebra from the beginning of the school year to the end of term 1. More specifically, the average scores on the achievement test for the control group at the end of term 1 ($M = 21.09, SE = 1.82$) were significantly higher ($t(31) = -8.991, p < .01, r = .85$) than the average scores at the beginning of the school year ($M = 10.47, SE = 1.38$). The results were similar for the emporium section. On average, the emporium section had significantly higher scores at the end of term 1 ($M =$

$21.03, SE = 3.06$) than at the beginning of the year ($M = 10.62, SE = 1.78$), $t(29) = -5.446, p < .01, r = .71$.

The differences in the average sub-scores (corresponding to term 1, term 2, and term 3-topics) between attempt 1 and attempt 2 on the achievement test were examined for both groups of students. The results indicated that the differences for the students enrolled in the control section were significant for term 1-topics average scores ($t(31) = -9.455, p = .00, r = .86$), but non-significant for term 2-topics and term 3 - topics sub-scores ($t(31) = -1.746, p > .05, r = .30$ and $t(31) = .442, p > .05, r = .08$, respectively). For the emporium section, the differences in average sub-scores were significant for term 1-topics and term 2-topics ($t(29) = -5.899, p = .00, r = .74$ and $t(29) = -2.319, p < .05, r = .40$, respectively). However, there was no significant difference between the term 3-topics sub-scores from the beginning of the year and the end of the first term ($t(29) = .571, p > .05, r = .11$).

After the first term of the school year the students enrolled in a three-week long accelerated term. During this period neither group of students had a mandatory mathematics class. After the accelerated term, the students had a three-week long winter vacation before the start of the second term. At the beginning of the second term, the students in both control and emporium sections were administered the achievement test in order to assess if and how the six-week long break from the math class affected their content knowledge. Comparing the average scores on the achievement test at the beginning of term 2 revealed that the emporium section had significantly higher scores ($M = 21.37, SE = 2.91$) than the control section ($M = 14.94, SE = 1.90$), $t(42.413) = 1.850, p < .05$ with a medium-sized effect, $r = .27$.

Next, we compared the average scores on the achievement test administered at the beginning of term 2 to the average scores on the achievement test given at the end of term 1 for both groups of students. The emporium section students did not score significantly different at the beginning of term 2 ($M = 21.37, SE = 2.91$) compared to the end of term 1 ($M = 21.03, SE = 3.06$), $t(25) = .790, p > .05, r = .156$. However, the control group scored significantly lower at the beginning of term 2 ($M = 14.94, SE = 1.90$) compared to their average scores at the end of term 1 ($M = 21.09, SE = 1.82$), $t(23) = 6.426, p < .01, r = .80$.

Finally, comparing the differences in average scores between the second attempt (at the end of term 1) and the third attempt (at the beginning of term 2) on the achievement test for both groups students revealed that on average, the control section had a significantly higher negative learning growth on the achievement test during this period ($M = -7.50, SE = 1.17$), than the emporium section ($M = -.87, SE = 1.49$), $t(48) = 3.463, p < .01$, with a medium-sized effect, r = .45.

Discussion

The main objective of this study was to examine the impact the emporium model of teaching had on academic achievement of students in the Algebra I course compared to the traditional approach to instruction. The student achievement levels in mathematics, measured at the beginning of the school year, indicated that the two groups of students (in the experimental group and the control group) were comparable in their prior content knowledge.

The average scores on the achievement test given at the end of the first term indicated no significant differences between the two groups. In addition, the comparison of the learning growth of students in the control group and their counterparts in the emporium section revealed no notable differences. This implied that the emporium model of instruction did not affect student learning more than the traditional method. Furthermore, given that the control and experimental groups had significant learning growth during the first term, it would appear that both approaches to instruction were equally effective in improving student math knowledge.

Although the overall average scores (for both control and experimental group) on the achievement test at the end of term 1 were significantly different compared to the scores from the beginning of the term, a further analysis of the sub-scores (corresponding to term 1, term 2, and term 3-topics) revealed differences between the control section and the emporium section. More specifically, the findings indicated that the traditional approach to teaching and learning (employed in the control section) impacted only the student content knowledge of the topics covered during the first term of the school year (term 1-topics sub-scores). However, the students in the emporium section demonstrated significant learning growth in both term 1 and term 2-topics. One possible explanation for this difference between the two groups of students may be the flexibility of students in the emporium section to choose the topics they wanted to learn. Although the emporium section also had a pre-determined path through the course content, their learning environment was online and many topics from term 2 and term 3 were accessible to the students in this group.

Overall, the findings revealed that over the course of 15 weeks (duration of term 1 of the academic year), the emporium model of teaching did not prove to be more effective in improving student content knowledge of mathematics than the traditional, lecture-based method. However, the results indicated that the students in the emporium section had better retention of the content knowledge acquired during this period. More specifically, the students in the control group scored significantly lower on the achievement test at the beginning of the second term (6 weeks after the end of term 1) compared to their scores on that achievement test at the end of the first term. The average scores of the emporium section students did not notably change from the end of term 1 to the start of term 2 (as shown in figure 2).

One may argue that the students in the emporium section had an uninterrupted access to their mathematics classroom through their online learning software (ALEKS) and were therefore able to continue working on mathematics during the accelerated term and winter break. To evaluate student engagement during this period, we examined the number of days the students worked on their algebra topics in ALEKS. In order to be considered to have worked in ALEKS, a student had to not only log into the online learning platform, but also successfully complete at least one math topic.

It can been seen from Figure 3 that only four students worked at least four days on their assignments in mathematics in ALEKS. The majority of the class, specifically 15 students, did not log into ALEKS at all during this period, while eight of them only did so less than four times. While the few students who continued to work in ALEKS during the time period between the two terms may have impacted the overall retention of knowledge of the emporium section students, it is improbable that was the sole cause of the high retention level of the entire group.

A more plausible explanation for the higher retention levels seen among the emporium section students may be based on the idea of mastery learning and how the respective course designs enable and promote it in the two sections of Algebra I. All students enrolled in this course, regardless of the section (control or experimental), were required to demonstrate mastery of each content unit by receiving at least 80% on the corresponding summative assessment. However, once the students in the control group demonstrated the mastery of the unit, they simply moved on to the next unit. With the exception of the end of the course assessment, these students never again completed another formal assessment on any of the previously mastered topics.

The approach to mastery in the emporium section of the course was notably different. The students completed topics in ALEKS by demonstrating the mastery of the content. However, the students also completed frequent assessments on random selections of topics that they had already mastered. If a student failed to correctly answer questions on these assessments, they had to remediate by repeating the corresponding lessons and assignments in ALEKS. By engaging in this reassessment practice, the students had to not only demonstrate their mastery of a particular unit, but also retain that knowledge and apply it at a later date. In case they did not retain a certain concept, it was assumed that they did not learn it adequately in the first place and they would have to remediate and reassess.

CONCLUSIONS

The current study looked at the achievement and retention of mathematics in the traditional format and emporium model sections of Algebra I. The duration of this study was the period between the start of the school year and the beginning of the second term. The future work includes examining both differences in achievement and retention between the two groups of students, if any, at the end of the academic year.

It is imperative to keep in mind that the goals of mathematics education extend beyond the boundaries of one assessment, one course, or even one grade. The objectives of teaching and learning in mathematics continue to focus on student ability to comprehend, retain, transfer, and successfully apply acquired knowledge. Although the format of teaching (traditional versus emporium) did not seem to affect student achievement in the mathematics course examined in this study, the retention of the mathematics content was very different for the two learning environments. The results of this study suggest that the emporium approach could result in higher retention of content knowledge after an extended period of time without a regularly scheduled mathematics class.

REFERENCES

ALEKS. (2014).What is ALEKS? Retrieved from http://www.aleks.com/about_aleks.

Algebra I Standards. (2015). Common Core State Standards Initiative. Retrieved from http://www.corestandards.org/Math/Content/HSA/introduction/.

Bloom, B. S. (1968). Learning for mastery. *Evaluation Comment*, *1*(2), 1–12.

Bloom, B. S. (1971). Mastery learning. In Block, H. R. (ed.), *Mastery learning: Theory and practice* (47–63). New York: Holt, Rinehart and Winston.

Bonham, B. S. & Boylan, H. R. (2011). Developmental mathematics: Challenges, promising practices, and recent initiatives. *Journal of Developmental Education*, *34*(3), 2-10.

Eyre, H. L. (2007). Keller's personalized system of instruction: Was it a fleeting fancy or is there a revival on the horizon? *The Behavior Analyst Today*, *8*(3), 317-324.

Grimes, D. & Warschauer, M. (2008). Learning with laptops: A multi-method case study. *Journal of Educational Computing Research*, *38*(3), 305-332.

Guskey, T. R. (2007). Closing achievement gaps: Revisiting Benjamin S. Bloom's "learning for mastery". *Journal of Advanced Academics*, *19*(1), 8-31.

Guskey, T. R. & Jung, L. A. (2011). Response-to-intervention and mastery learning: Tracing roots and seeking common ground. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(6), 249-255.

Keller, F. S. (1968). Goodbye teacher…*Journal of Applied Behavior Analysis*, *1*(1), 79-89.

Kulik , C. C. Kulik , J. A. Bangert-Drowns , R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research*, *60*(2), 265-299.

Mathematics Standards. (2015). Common Core State Standards Initiative. Retrieved from http://www.corestandards.org/Math/.

Twigg, C. A. (2003). Improving learning and reducing costs: New models for online learning *EDUCAUSE Review*, *38*(5), 29‑38.

Twigg, C. A. (2011). The math emporium: A silver bullet for higher education. *Change*, *43*(3), 25-34.

Twigg, C. A. (2004). Using asynchronous learning in redesign: Reaching and retaining the at-risk student. *Journal of Asynchronous Learning Networks*, *8*(1), 7-15.

Figures

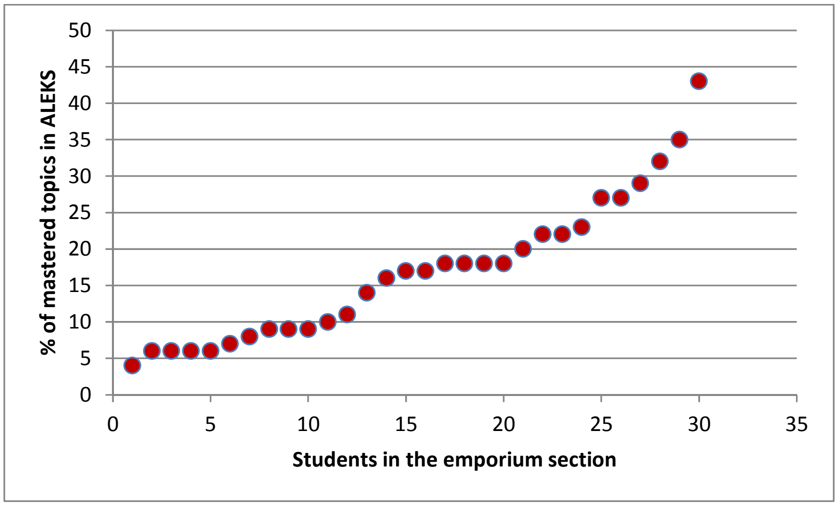

Figure 1. Initial percentage of mastered topics in ALEKS per student.

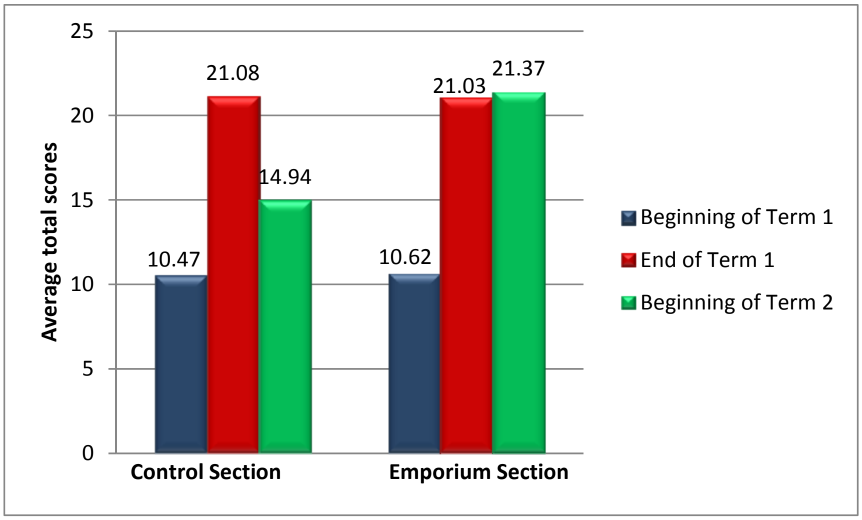

Figure 2. Student learning growth from the beginning of term 1 to the beginning of term 2 for both groups.