

RESEARCH ARTICLE

Enhancing the Success of College Algebra Students by Incorporating Adaptive Technologies

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Abstract

College students in the United States often enrol in introductory mathematics courses to acquire skills and knowledge that will enable them to solve related problems in their careers and daily activities. However, previous studies have shown limited levels of improvement that perpetuate a lack of proficiency. As a result, the gap in performance between top students and those at the bottom continues to increase. Using modern technology has been suggested as part of the solution to help students resolve their difficulties in mathematics and achieve better learning outcomes. This study assesses the longitudinal effect of redesigning College Algebra classes at a large public university, switching from a modified emporium model to a lab-based adaptive model. The results show that after redesigning the course, the pass rate increased from 68% to consistently being over 80%, while the withdrawal rate fell from 8% to 3%.

Keywords: Adaptive technology, College Algebra, ALEKS, personalised learning.

1. Introduction

Most college students in the United States today have constant and unlimited access to the internet, as well as a variety of technologies and mathematical tools that are available online. As a result, teaching and learning mathematics has been irrevocably altered in recent years to include distance learning, Massive Open Online Courses (MOOCs), and blended approaches that combine traditional lectures with online homework. Along with incorporating the various aspects of social media, these new technologies enable instructors to design courses that synchronize with the learning process and target specific needs (Engelbrecht, et al., 2020).

Included in these pedagogical innovations is the current trend of teaching College Algebra in a computer lab rather than a traditional classroom, which has prompted research educators to reassess didactic theories. A lab-based setting allows for intelligent tutoring systems to be used, which were shown in a meta-analysis of 50 studies by Kulik and Fletcher (2016) to raise test scores by 0.66 standard deviations, or from the 50th percentile to the 75th. One version that has attracted a lot of attention is active learning within an emporium model, first developed at Virginia Tech, which eliminates lectures and replaces them with a learning resource centre model featuring interactive software and on-demand personalised assistance. It allows students to choose what types of learning material to use depending on their needs, and how quickly they work through the curriculum. While requiring a significant commitment in terms of upfront cost and maintenance (Jones, 2016), the emporium model allows for multiple introductory courses to be taught using a staffing model that combines faculty, graduate teaching assistants, peer tutors and others who respond directly to the specific needs of students and direct them to the appropriate resources from which they can learn (Twigg, 2011).

Various modifications of the emporium model have been used to help researchers collect data. Most relevant to the current study is the work done by those who have explored the use of the emporium model in teaching College Algebra. Vallade (2013) found that College Algebra students in an emporium

setting had higher passing rates and overall scores, along with lower withdrawal rates, versus those taking the class in a traditional setting. The p-values indicated a statistically significant difference, though effect sizes were modest. A subsequent study by Cousins-Cooper, et al. (2017) found that students in emporium sections outperformed students in the traditional sections of College Algebra on the end of semester test by 12.63 percentage points, asserting that the results provide evidence that students at that level learn better by doing mathematics in an emporium rather than passively listening in a traditional setting.

In this study, we replace the emporium model and use adaptive learning technology to provide personalised instruction. Adaptive learning incorporates artificial intelligence to help students learn the content and assesses them on a regular or continuous basis. The concept of mastery learning is an important aspect of adaptive learning, which requires students to fully comprehend one topic or concept before moving to the next. Studies have shown that mastery learning can improve student outcomes in mathematics (Block & Burns, 1976; Kulik, et al., 1990), with Childers and Lu (2017) showing that the number of topics mastered is a significant predictor of final grades in foundational mathematics courses.

1.1. Background to the current study

In an effort to enhance the College Algebra course, various stakeholders at a large public university in the Southeastern United States, including departmental teaching staff, teaching assistants, and administrators collaborated to focus on changing the instructional methods to improve student performance, reduce the withdrawal rate, and improve student perception. Developments in the redesigned course were supported by regular conversations that took place before and during the implementation. Given that the primary aim was to increase student success, it was important to initiate and engage in discussions that specifically focused on the factors and constraints that affect attainment. These factors included the curriculum, instruction, assessment, process challenges, the development of a growth mindset, and the importance of incorporating previous research.

Expanding on these in turn, conversations involving the primary author and departmental collaborators allowed reflection on the state-mandated curriculum and how it was being enacted in the classroom. Other areas of focus included the need to address classroom diversity, promote equity, meet with students having special needs, and discuss the possible ways in which the new College Algebra format could be used to transform other courses. Regarding instruction, the discussion centred on effective pedagogical strategies, increasing student participation, and the viability and sustainability of new ideas. Assessment was considered in a manner designed to promote student learning, be attentive to the views of students regarding topics that pose particular difficulty, promote fairness, and the importance of assessment for summative, formative, and motivational purposes. Potential challenges and constraints were identified and reflected upon, along with the consideration of subsequent issues that could arise from modifying the course which could make further progress more difficult. Developing a growth mindset in students was discussed, thereby challenging the belief in a fixed mindset, where the ability of students in mathematics is predetermined (Boaler, 2013; Sun, 2018). Finally, a more general discussion took place involving the importance of utilizing recognised quantitative and qualitative techniques when conducting related research. The link between these factors is shown in the figure below.

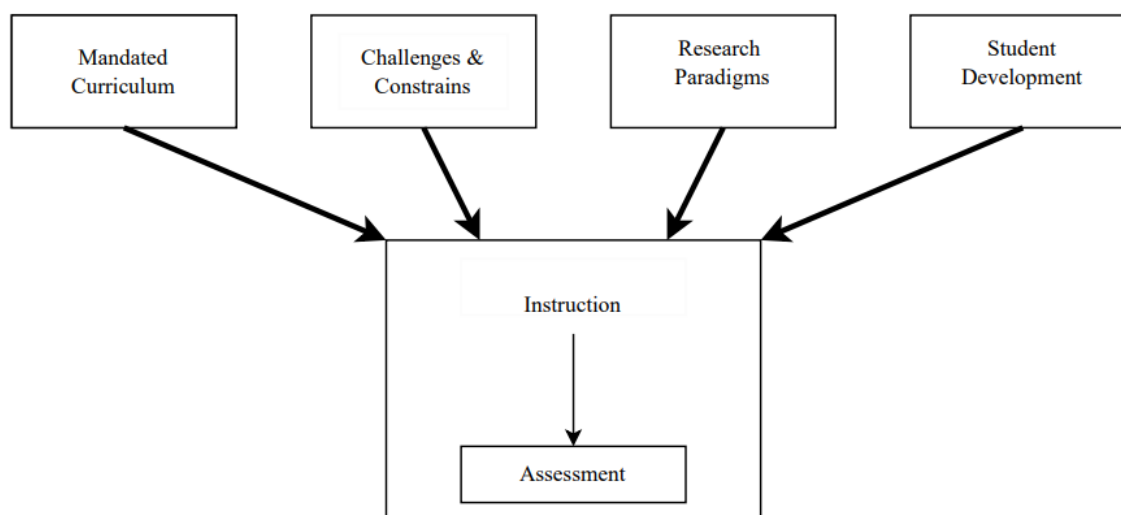


Figure 1: Factors guiding the redesigned course

1.2. Description of the course redesign

Prior to 2016, College Algebra students were taught according to a modified emporium model whereby they attended lectures for 50 minutes in a large auditorium in addition to engaging with computer-based learning for 3 hours per week in a laboratory. The online learning platform, MyLabsPlus, had no adaptive features at that time and was a one-size fits all platform consisting of weekly homework and quizzes. In the computer lab, students received on-demand assistance from the staff on duty. The staff comprised an instructor, graduate teaching assistants (GTAs), and learning assistants (LAs). By contrast, students taking the redesigned course in spring 2016 met two days per week for 75 minutes in the computer lab with their instructor, along with an instructional team comprised of GTAs and LAs ready to provide personalised help. During their class time, students used ALEKS (Assessment and Learning in Knowledge Spaces), a web-based adaptive learning system, and were involved in active learning through short lectures, class activities and problem solving. The system determined the topics that each student had mastered as well as the topics they had not, continually updating the student's knowledge map as they continued to learn new topics. The course material was divided into weekly objectives, but students could work on any course material (past or future) if they completed the current objective. At the beginning of the class period, the instructor or a graduate teaching assistant delivered a short lecture of approximately 15 to 20 minutes duration, and then during the remaining class time, students were encouraged to work on their assignments and ask the instructional team questions related to the course material. In addition, students had to take three non-adaptive midterm exams and a non-adaptive final exam, all of which were given in the computer lab. In contrast to the weekly assignments, the midterm and final exams were 'static' to avoid being affected by the adaptive nature of the ALEKS system and thus ensure that all the students were tested on the same types of problem.

2. Theoretical Framework

Keller (1967) and his colleagues noted significant improvements following the introduction of a personalised method of instruction which consisted of five features that distinguished it from the conventional method of teaching (Keller, 1968). These features are summarised below and explained in terms of how they are implemented in the current study:

1. Self-paced instruction – The student is allowed to move through the course at their own speed. Factors that determine the speed of learning include the student's ability and activities that affect the

student's availability to study. The instructor, in this case the adaptive learning system, creates a plan for the student, but the speed of learning is the student's choice.

2. Unit perfection – One important feature of the ALEKS system of personalised instruction is that the course is divided into units. The student is required to master one unit before proceeding to the next. The course material is designed prior the semester and the material is divided into units or objectives. Students who fail to master a certain unit are redirected by the adaptive systems to previously covered topics and given another test for assessment.

3. Lectures and demonstrations – A distinguishing feature of personalised instruction is the use of fewer lectures and demonstrations to motivate students, rather than them being primary sources of information. The lecture time in this instance was limited to 15-20 minutes per class meeting. During the lectures, only the topics in the current objective that many students struggle with were presented, which were identified through reports generated by the learning system.

4. Written materials – The Keller Plan emphasizes the use of written materials in teacher-student communications. Written materials allow students to study at their own pace and are portable, easy to review, and easy to annotate. The instructor's class notes were posted online prior to the class meetings in the learning management system to enable students to progress at their own pace.

5. Proctors – Humans play a vital role in the implementation of Keller's ideas. According to Keller (1968), proctors facilitate testing, tutoring, and immediate scoring. Proctors also enhance the personal-social aspect of teaching. In this instance, the instructor can permit early testing if specific criteria are met, while the instructor, undergraduate learning assistants and graduate teaching assistants are always available to address student questions and provide tutoring.

3. Research Questions

This quantitative study builds upon the ideas of Keller (1967, 1968) and seeks to answer the research questions below regarding the impact of redesigning College Algebra using the ALEKS web-based adaptive learning system.

1. What is the impact of the redesigned College Algebra course on the passing rate of students?
2. What is the impact of the redesigned College Algebra course on the withdrawal rate of students?

4. Methodology

The research design for this project was non-experimental. The final letter grades of the students were collected from the institutional database, with the aim being to explore if there were differences in the passing and the withdrawal rates before and after restructuring the course, along with an analysis to determine whether the differences were statistically significant.

The participants in the study consisted of all students enrolled in College Algebra at a large public university in the Southeastern United States during the spring semesters from 2015 to 2019. The students were placed into the course based on the scores they obtained when taking the university's placement test, along with those who had recently passed the prerequisite Intermediate Algebra course, and those retaking the course due to low grades when enrolled in the past.

The total number of students enrolled in the course during the first semester considered, Spring 2015 was 1008, while during the first semester of the redesign, Spring 2016, the number was 1250. This increased in subsequent years to 1296 in the Spring 2017 semester, 1343 in the Spring 2018 semester,

and 1491 in the Spring 2019 semester. The course was coordinated between the different sections, with all the students completing the same online homework assignments and tests.

The overall grades obtained by the students in the course were obtained from the institutional data base, compiled in an Excel spreadsheet, and then uploaded into SPSS (Version 26). The SPSS software was used to do the statistical analysis and obtain descriptive and inferential results, with the final letter grades coded as numerical values.

5. Results

To answer the first research question, final grades of A, B, and C were considered passing. The passing rates during the spring semesters from 2015 to 2019 are shown in Figure 2. As can be seen, the passing rate increased substantially from 68% in spring 2015 to a consistent figure of over 80% once the redesign took place.

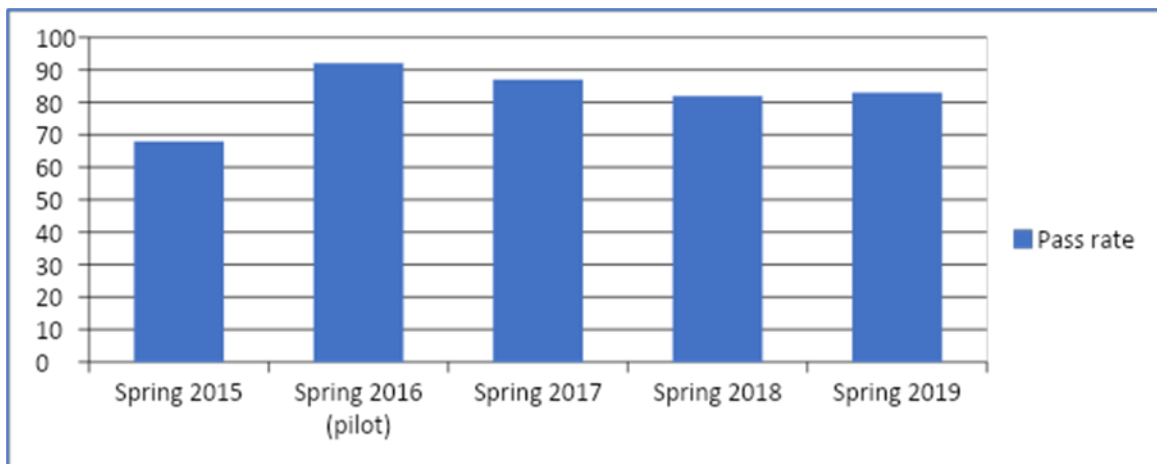


Figure 2 – Passing Rate of Students by Semester

For the second question, grades of W and WM (medical withdrawal) were considered as withdrawal. The withdrawal rate fell from 8% to a steady rate of around 3%, as can be seen in Figure 3.

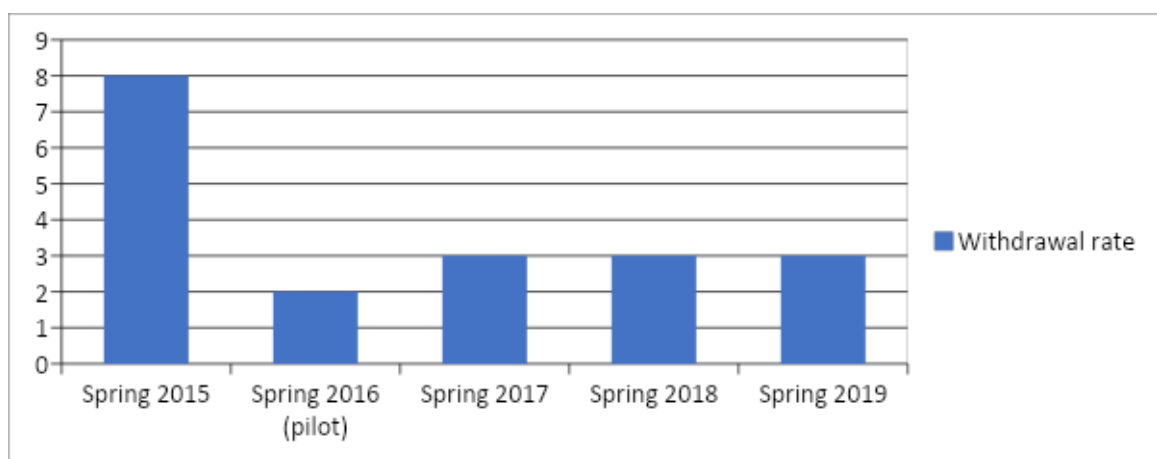


Figure 3 – Withdrawal Rate of Students by Semester

6. Discussion

This study explored student performance in College Algebra after changing the course structure and replacing the modified emporium model via the implementation of adaptive learning technology. The first semester included in the study (and used as a baseline) was the last semester when the modified emporium model was used to teach the course, while subsequent semesters included covered the period that the course redesign was adopted. Although it was intended to continue collecting data in 2020 and subsequent years, enforced changes made to the course structure and delivery caused by the Covid-19 pandemic made any further comparisons invalid.

The increase in the passing rate and the decrease in the withdrawal are in line with the studies by Hagerty, et al. (2005, 2010), Kasha (2015), Kulik & Fletcher (2016), and Boyce & O'Halloran (2020) suggesting that the redesign of College Algebra instruction methods using the ALEKS web-based adaptive learning system helps improve student success in the course. However, in this study we also considered the longitudinal effect of implementation and involved a much larger population of students. The results show that passing rates improved significantly after the changes made, from being below 70% to consistently being above 80%. At the same time, the study found that the withdrawal rate of students dropped from around 8% to a consistent rate in the following years of around 3%.

The results corroborate theoretical justifications for personalised learning advocated by Keller (1967, 1968) and more specific aspects required to implement such a tailored mastery system that consists of individual pacing, unit mastery requirements, written instructional materials, and student proctors (Thompson, 1980). It should be noted that while we did not seek student perceptions of adaptive learning in this study, one should not be take for granted that adaptive learning is necessarily popular or viewed as being beneficial, even when test scores and overall grades improve (Stuve, 2015). Careful implementation that incorporates all the stakeholders is therefore of critical importance when successfully carrying out changes to existing courses, with Sun, et al. (2021) supporting the contention of Griffiths (2015) in concluding that adaptive technologies provide a bigger boost to student learning when supplementing rather than replacing traditional instruction.

7. Conclusion

Adaptive technologies can radically alter the learning process, along with the organization of knowledge, and how this knowledge is accessed. In this study, we found that by modifying a course to incorporate the principles of personalised learning, the pass rate improved in a statistically significant manner, along with a reduction in the withdrawal rate. While the results are extremely encouraging, the current study was limited to the redesign of one course at one institution and may not generalize to a wider student population. The long-term effects of the redesign were not analysed in subsequent mathematics courses and is something that requires further study. There may also have been factors beyond the scope of this study that affected student performance, such as the instructors teaching the redesigned course. Finally, given that there are now several adaptive learning systems used in introductory college mathematics courses, it would also be natural to make quantitative comparisons of student attainment between them. In the meantime, we believe that the findings of this study can advise both higher education administrators and instructors of mathematics, especially those who teach in computer laboratories.

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