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Utilizing an Emporium Course Design to Improve Calculus Readiness of Engineering Students

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Utilizing an Emporium Course Design to Improve Calculus Readiness of Engineering Students

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Abstract

The intervention has targeted incoming students in Engineering and Computer Science degrees at the University of Texas – Pan American. Participating students were selected who had a record of participation in Pre-Calculus classes in high school, but who had not demonstrated their readiness to take Calculus, as measured by placement tests and existing credit, which applies to a significant number of entering students. The course design uses an emporium method, specifically the Assessment and Learning in Knowledge Spaces (ALEKS) software, in a computer lab to deliver to students an intensive program of mathematical practice and exploration. The course design is meant to take advantage of students' existing knowledge, rewarding them for it in fact, and focus them on specific Algebra and Trigonometry topics in which they need more practice and one-on-one instruction[1,2].

The purpose of this activity is to accelerate the Calculus preparedness for a subset of students held back due to standardized test scores and perhaps limited mastery of the prerequisite content. The benefits we aim to show are improved engineering readiness, reduced time-to-graduation, and improved performance in gatekeeper courses. In this report we show the results of the first cohort, which did improve the Calculus placement for most students and were significantly more successful at doing so than a traditional Pre-Calculus class, although the subsequent improvement in performance in the Calculus 1 course was not statistically significant.

Keywords

Mathematics Placement, Emporium Models.

Introduction

The University of Texas – Pan American is a minority serving institution in Texas. The student population is predominantly made up of students from the local region, which includes two of the poorest counties in our state. The region has significantly lower levels of educational

attainment and median incomes compared with the state as a whole. Most students are first generation college students. The student population is 90% Hispanic, and more than 80% of them are bilingual in Spanish and English. The College of Engineering and Computer Science at the university offers Bachelors degrees in Mechanical Engineering, Manufacturing Engineering, Electrical Engineering, Civil Engineering, Computer Engineering, and Computer Science.

Typically more than 50% of first-year Engineering and Computer Science students do not place into Calculus for their first semester. A fifth to a quarter of the students are placed into College Algebra. Given prerequisites for foundational courses in engineering such as Physics, this effectively delays the students' time-to-graduation by at least a year. Though they can attempt to catch up in the summer semesters, the abbreviated and intense nature of summer Calculus and Physics courses can also inhibit the student's mastery of later coursework in their engineering program.

We also see a significant number of first-year students at the university with high school transcript Calculus courses, but without credit for those courses through the AP test or other mechanisms. Many are placing into College Algebra and not Pre-Calculus through the use of standardized placement tests or through not taking a placement test at all. Studies of students in College Algebra courses in Texas indicate that rates of test aversion and anxiety are high for students in these courses[3].

Engineering students who do not take Calculus 1 or 2 in the Fall of their first year are substantially behind the curve because Calculus is the primary gatekeeper to sequences of courses in each of the Engineering and Computer Science degree plans.

To overcome this difficulty of first-year Engineering and Computer Science students not placing into Calculus despite educational backgrounds which indicate some experience with Calculus or its pre-requisite topics, we have piloted a summer bridge intervention that uses a specialized mathematics course, mentoring, and engineering design challenges. The program targets students who have requisite high school coursework to enter Calculus, or even high school experience in Calculus, but who have placed into College Algebra. Students will have satisfied, via the Texas Success Initiative Assessment Test, only the college readiness standard in mathematics. See the link in reference [4] for details on the Texas Success Initiative requirements for college readiness in students.

The question we hope to answer in this study is: can the calculus readiness of students be improved through an intervention designed to take advantage of their prior experiences in advanced mathematics in high school, that is through the use of an emporium model of instruction? We will show here that for the first cohort we did successfully transition 17 of 22 participating students into a Calculus 1 course who would otherwise have started their first semester in a Pre-Calculus or College Algebra course. This is a significantly higher success rate than has been found in other Pre-Calculus courses including other courses with an Emporium model intervention. One possible reason for this is that the students are self selecting as more mathematically adept than their peers. Of those students, 16 enrolled in a Calculus 1 class in the

Fall semester and 10 of them successfully completed Calculus 1 with an A, B, or C. While this is an improvement in the passing rate over general Calculus 1 students, it is not statistically significant. A primary goal for the next iteration will be to show a significant improvement in performance in the Calculus 1 course, mainly by identifying fundamental topics necessary for student success in Calculus 1 at our university, a secondary goal of the research project is to identify possible causes for the low performance of students who do not complete the summer program, with the long term aim of improving the chance of students to successfully complete the initiative and Calculus 1. In the first cohort we identified full time summer employment commitments as a common feature for 4 of 5 students who did not complete the course objectives.

Emporium Model

The mathematics course is a specialized course combining material from the College Algebra, Trigonometry, and Pre-Calculus courses. Material is chosen based on feedback from Calculus instructors at the university on specific problems and techniques in which the student population in their courses is deficient. The course in particular covers more topics in Algebra and symbolic manipulation than a traditional Pre-Calculus and Trigonometry course would. The course is structured as a partial emporium model class. The emporium model involves students using a computer program such as the Assessment and Learning in Knowledge Spaces (ALEKS) in a computer lab[5]; the students spend class time answering questions in the system and also use the system for their homework assignments. The instructor, along with student mentors, circulates through the lab providing one-on-one assistance for problems students struggle with.

The software is adaptive, and provides each student with an individualized version of the course. The first activity of the students is to take an initial assessment that attempts to identify what prior knowledge they have entered the course with. This is especially important for courses that are an initial step in a chain of mathematics courses, as with traditional mechanisms of placement students are entering the course with a wide variety of experiences. The software effectively rewards students for retaining prior knowledge, which is significantly different from a standard course design[5,6,7].

The emporium model is being used on many campuses for students who place into remedial mathematics courses. It is used at our university in remedial mathematics classes as well as sections of College Algebra and the Elementary Probability and Statistics courses. The emporium model works based on the hypothesis that students who have spent more time on task with the material from the class will have better mastery of the material, and will perform at a higher level in subsequent courses which depend on that material. Emporium model courses have shown large increases in the percentage of students completing their remedial mathematics courses at our university, and increases in students completing their college level mathematics courses. This course design incorporates many of the features of mastery-based courses. Students are not allowed to proceed until they have demonstrated mastery of earlier material.

The model differs from a normal course design:

- Unlike a normal class, students will do as many problems as necessary to become proficient in each concept under the supervision of an instructor or mentor.
- Students are rewarded for already knowing some of the material. Students are able to quickly move through material they already know, and can focus their time on new material or concepts they have failed to master.
- Students get one-on-one help with an instructor or mentor when they need it.
- Spanish versions of the software (ALEKS) are available and easily accessible.
- Students move at their pace, rather than that of the class.
- Students are given the freedom to decide what they want to work on, which has been shown to increase educational effectiveness in middle and grade school children[8].

This approach differs from other emporium models in that we are targeting the intervention specifically at Engineering majors. We are including student mentors from their major as the in-class and out of class assistants. Finally the course includes design challenges through a partnership with the Railway Safety Center at our school; design projects were chosen which emphasize applications of algebra and trigonometry in railway engineering, and included a tour of the laboratory spaces used by the center.

If successful, a student will be Calculus ready for the fall semester of their first-year. The intervention is producing students who have higher pass rates in Calculus 1, and higher GPA. However, for the first cohort we did not find that these higher rates were statistically significant. Still, by accelerating Calculus readiness and providing a learning environment that promotes general college readiness, we should have reduced time-to-graduation and hope to show improved knowledge mastery in later courses, especially those that are Calculus or Mathematics intensive.

Enrolled Students

The first cohort entered the program in Summer 2014. We had 22 students, all had placement into our College Algebra or Pre-Calculus course (a difficulty was finding enough interested students from just the College Algebra placement). All had non-college credit Pre-Calculus on their high school transcript, and ten had prior experience in a Calculus course from high school, however they had not received college credit for the course. The program was run through the university as a special section of the Pre-Calculus course, and we will compare the success rates with the other sections of Pre-Calculus. In the Fall semester three sections of Pre-Calculus were run as Emporium courses using the ALEKS software; these courses did not include the student mentors or an engineering design project, but otherwise used the same course materials as the summer program. There was also a section of Pre-Calculus run in the Fall semester that was fully online. All other sections of Pre-Calculus were traditional, largely lecture-based courses with

students who either placed into the section or had completed College Algebra in a previous semester. Table 1 gives the results and grade distributions for the various flavors of Pre-Calculus offered in Summer 2014 and Fall 2014.

Table 1: Pre-Calculus grade distribution

Grades	**A**	**B**	**C**	**D**	**F**	**DR/W**	**Total**	**ABC %**	**DFW %**
Summer 2014 Traditional	11	10	13	8	9	63	114	29.8	70.2
Summer Bridge	10	4	3	4	1	0	22	77.3	22.7
Fall 2014 Traditional	13	21	21	16	32	50	153	35.9	64.1
Fall 2014 Emporium	6	6	16	9	38	13	88	31.8	68.2
Fall 2014 Online	7	6	2	0	10	10	35	42.9	57.1

We observe that the success rate of students in the Summer bridge program differed significantly from that of the other Pre-Calculus sections. Most likely students who elected to participate in this summer bridge were self-selecting as mathematically ahead of their peers in general College Algebra and Pre-Calculus courses. They were declared as Engineering or Computer Science majors; they had some level of College Preparedness; and they elected to take a mathematics course prior to their first official semester as first-year students. Evidence that this population is special is that the effort needed to find 22 interested students for the first cohort was extreme. It is notable that attendance for the course was nearly perfect with no absences and only two tardies. Also note that no students dropped or withdrew from the course (their final grade would affect their GPA and potentially financial aid for AY2015-2016).

Of the 5 students who were not successful in the program, we found that 4 had significant work commitments outside of class. In the next iteration we will place a restriction on how much outside commitment students may have.

Time on Task

A key difference of the emporium model course design used for this project from a more traditional course design is the amount of time that students spend with the course material. The ALEKS component of the course was composed of 205 topics, each topic representing a question type. For the students targeted in this intervention, and with success in Calculus 1 as the goal, topics were chosen from Algebra, Trigonometry, and Pre-Calculus; input was solicited from Calculus 1 instructors about observed deficiencies in the student population of Calculus 1. The class met in a computer lab for 2 hours per day, 4 days per week for 6 weeks. This gave a total time of 48 hours in class working with the software. Friday each week was spent working on the Engineering Design Challenge that was part of the course.

In addition to the 48 hours in class with the software, students were asked to use the software for homework, see Table 3. The ALEKS software requires that a student answer a question correctly three times without help before it records that topic as known. Students are given periodic

assessments that check whether they are retaining topics they have finished, and a student may gain topics through assessments by demonstrating that they have mastered them. Student grades in the course were assigned based on the number of topics completed out of the 205 assigned, the amount of time spent with the software, their work on the design challenges, and their scores on the final exam.

Figure 1 plots the students' scores on the final exam versus their total time logged in and working on homework problems with the software. We see little correlation between this score and time with the software. Possibly this is due to the level of prior knowledge that some students entered the program with. In lower level courses we have found a stronger correlation between time with the software and performance on final assessments. Figure 2 gives the number of topics completed versus the total time logged in and working on homework problems with the software.

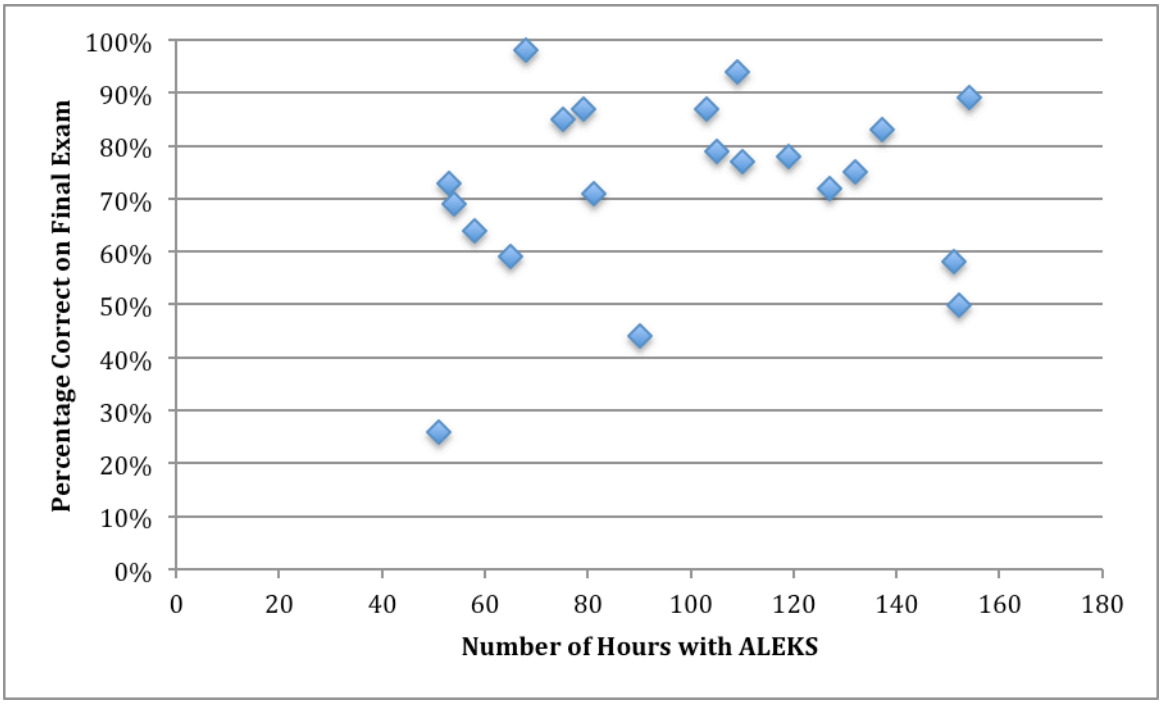

Figure 1: This chart shows the student percentage correct on the course Final Exam versus the time on task logged by the software. Time data for one student is missing due to a software issue.

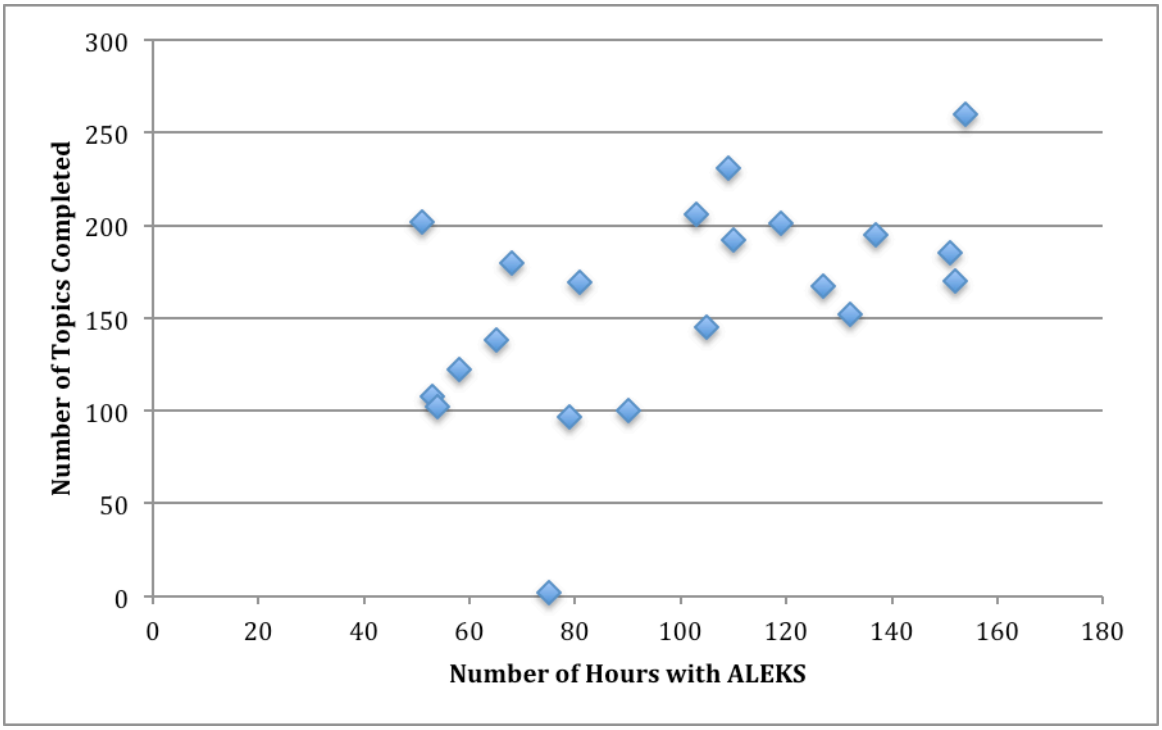

Figure 2: This chart shows the student time on task versus number of topics marked as completed. Time data for one student is missing, and the outlier with 75 hours and 2 topics are due to software issues.

Success in Calculus 1

Of course the real measure of success for the program is how the students do in the subsequent mathematics (and mathematics intensive) courses. All but one of the passing students enrolled in a Calculus 1 course for the Fall 2014 semester. The one exception was a student who took the summer bridge as a concurrent enrollment student; due to him being a minor, and being in a unique situation we have not been able to secure permission to include his current activity in this report. Table 2 summarizes the grade distribution from the Fall 2014 sections of Calculus 1, and from the students who participated in the summer bridge program. Using a hypergeometric distribution we find that a random sample of 16 students from the Fall 2014 Calculus 1 classes would have a 20.5% chance of having 10 or more students successfully passing the course. So we cannot conclude that the success rate was statistically significant for this population. Likewise the Calculus 1 GPA of students who successfully completed the bridge program was 1.8 on a 4.0 scale, compared with a 1.55 from the general Calculus 1 classes. However the chance that a random sample of 16 students from Calculus 1 had a GPA of 1.8 or higher is 26%, so again we cannot conclude that this change was statistically significant.

Figure 3 shows the grade in Calculus 1 in Fall 2014 for students who successfully completed the summer bridge program versus the time they spent on task in the summer program. Again we find little to no correlation, however it is interesting that there is a cluster of "B"s at the upper end of the time scale. Figure 4 shows the grade in Calculus 1 in Fall 2014 for students who successfully completed the summer bridge program versus the number of topics marked as

mastered by the software (obtained through repeated success in software assessments and by answering the question correctly three times without asking for help). It is important to note that throughout the emporium course it is possible for a student to have a topic marked as mastered removed because of a periodic assessment. Here we see a correlation, indicating that we almost certainly need to be including a minimum number of topics as a requirement for completing the program. This table and subjective questionnaires of the Calculus 1 instructors are going to be used to adjust the focus of the topics to better address Calculus readiness.

Table 2: Grade distribution in Fall 2014 Calculus 1

Grade	**A**	**B**	**C**	**D**	**F**	**DR/W**	**Total**	**ABC**	**DFW**
Fall 2014 Calculus 1	64	63	78	42	55	114	416	205	211
	15%	15%	19%	10%	13.2%	27.4%	100%	49.3%	50.7%
Summer Bridge Students in Calculus 1	1	4	5	3	1	2	16	10	6
	6%	25%	31%	19%	6%	13%	100%	63%	37.5%

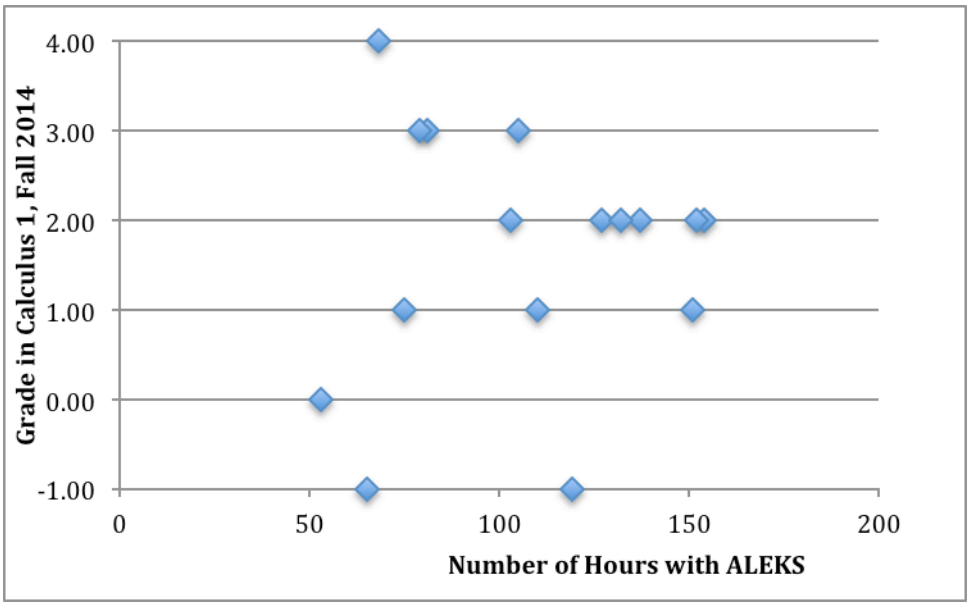

Figure 3: This chart shows, for those students who went on to Calculus 1 in Fall 2014, the time on task they had in the Bridge Program versus their grade in Calculus 1. 4 is an A, 3 is a B, 2 is a C, 1 is a D, 0 is an F, and -1 is a Drop.

Adjustments and Conclusion

The program successfully transitioned 16 students to Calculus 1 for the Fall semester of their first-year; of these, 10 successfully completed this Calculus 1 course. A success rate that is comparable for that of students who place into Calculus 1 via other mechanisms. These 10 students are now registered for combinations of Calculus 2 and Calculus based Physics 1 for the

Spring 2015 semester, and we will follow up on their performance in these classes in our future reports. They are one or two full semesters ahead of where they would be in their mathematics course sequence for the Engineering and Computer Science major if we had not conducted the intervention and they had registered for Pre-Calculus or College Algebra. One conclusion is that the Department of Mathematics may be able to successfully make use of students' high school transcripts for placement decisions and not rely solely on placement test scores.

A number of deficiencies of the program need to be addressed for future cohorts. On the one hand Figure 4 indicates that we need to increase the passing standard for the course to include a minimum subset of the included topics. We transcripted the program as a Pre-Calculus course. This allows the program to be sustainable after the funding period, and enables the program to be transferable to other schools. However because of this, the grades earned by students count towards their GPA and financial aid computations (namely by affecting their completion percentage). For this reason we need to minimize the number of students who enter the program and are not successful. In the first cohort in Summer 2014 we identified full time summer employment as a consistent marker for these students; they also had some of the lowest number of hours logged in the course. Future cohorts will be requiring that students have only a limited amount of summer employment during the period the program runs.

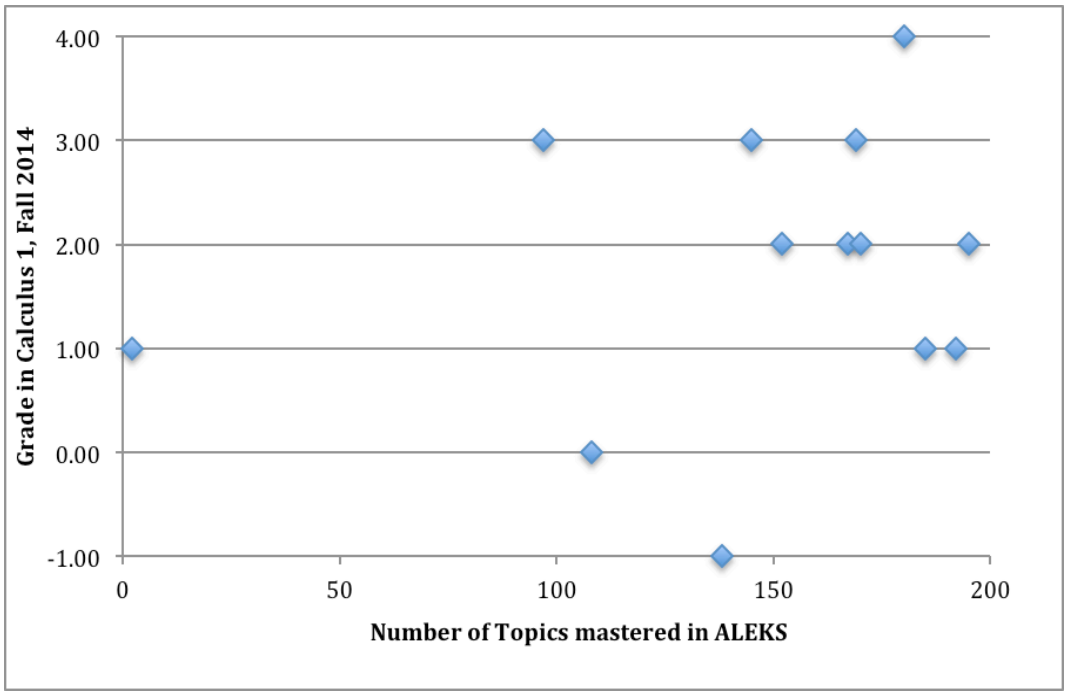

Figure 4 - This chart gives for those students who went on to Calculus 1 in Fall 2014, the grade they received versus the number of topics that they mastered in the summer bridge program.

Observation of students indicated that the program might have been increasing the speed with which they did mathematics computations. However we had not set up the investigative protocols to measure this. Future cohorts will have a protocol included to study whether students are improving both quality and speed of their mathematical computations.

Finally alignment with the expectations of Calculus 1 instructors needs to be improved. The course content emphasized heavily algebra and symbolic manipulation techniques as instructors identified this as a need. However, it may have come at the expense of an expertise with trigonometric functions. Course content will be adjusted to address this, and a minimum set of topics for finishing the program will be included in future syllabi. The goal is for students who complete the program to have a very high likelihood of success in Calculus 1, and the next iteration will see adjustments to course content to attempt to make this improvement.

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