AC 2007-1998: BENEFITS OF A TUTORIAL MATHEMATICS PROGRAM FOR ENGINEERING STUDENTS ENROLLED IN PRECALCULUS: A TEMPLATE FOR ASSESSMENT

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Benefits of a Tutorial Mathematics Program for Engineering Students Enrolled in PreCalculus: A Template for Assessment

Abstract

An interactive online tutorial program (ALEKS) was the focus of an engineering course created to increase the success of engineering students in a Precalculus class. Engineering students were embedded in two Precalculus courses with other students. An assessment rubric for measuring the effect of ALEKS on Precalculus grades of engineering students was developed and tested. While some of the results were not statistically significant, ALEKS was shown to have a generally positive effect on the math grades of students enrolled in the engineering course.

Introduction

In fall 2006, the total undergraduate enrollment of Boise State University reached 16,017, of which 1,296 were enrolled in the College of Engineering. Approximately 61% of the university student body attends full-time. The fall 2006 freshman engineering enrollment is 440, in majors encompassing civil engineering, electrical engineering, materials science and engineering, mechanical engineering, computer science, construction management and undeclared engineering. The first-time, full-time freshman retention rate for Boise State University is 64% for engineering students, and 63% overall.[1] This is low when compared with the national average[2] of all four-year institutions, 69% and provides strong motivation for investigating ways to increase freshman success.

This study focuses on helping students succeed in Precalculus, a 5-credit mathematics course, in which 84 first-semester engineering students were enrolled in fall 2006 (19% of the incoming freshmen engineering class). An additional 37 engineering students classified as non-freshmen also enrolled in Precalculus (transfer students, repeat takers, etc.). These 121 engineering students were enrolled in ten sections of Precalculus which had an average enrollment of 33 students per section, with engineering students thus comprising 28% of the overall Precalculus enrollment. In fall 2006, the Precalculus "success rate," defined as being the percent of students receiving an A, B or C grade, compared with all students enrolled (including A, B, C, D, F, and withdrawn students), was 58%; 189 out of 326 enrolled students passed Precalculus.

In an effort to increase the retention of pre-Freshman engineering students, two sections of a 4-credit, non-compulsory engineering course, ENGR 110 were offered for engineering students that were co-enrolled in Precalculus. The University enabled the construction of two Learning Communities intended to foster student retention at the University level. Each section of ENGR 110 was paired with an introductory English course (ENGL 101) and a Precalculus section. Engineering students enrolled in Learning Communities were assured reserved spaces in specific sections of ENGR 110, Precalculus, and ENGL 101, ensuring that the same students are embedded within the same sections of each course.

Two of these Engineering Learning Communities were established, corresponding with each section of ENGR 110. Enrollment in the Learning Communities was accomplished through summer advisement programs for incoming students. ENGR 110 included retention and introductory activities and exercises; however, ALEKS was the principle focus of the course, and the grade in ENGR 110 depended mainly upon online assessments of ALEKS progress and attendance. The learning community is conceptually illustrated in Figure 1.

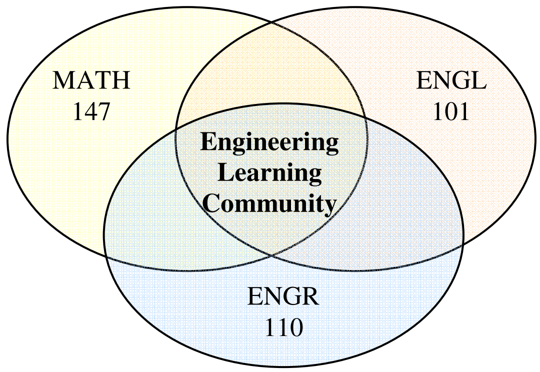

Figure 1: Venn diagram illustration of Engineering Learning Community for freshmen.

ALEKS (Assessment and LEarning in Knowledge Spaces) is a web-based, artificially intelligent assessment and learning system that uses adaptive questioning to determine what a student knows and what they do not yet know in a course. ALEKS then instructs the student on the topics that the student is ready to learn. Periodic assessment is done during the course, in a way that is scheduled automatically (ALEKS) or by the instructor, to ensure retention of course material. ALEKS was developed from an assessment and teaching system for Arithmetic that was based on Knowledge Space Theory. [3] This early development was financed by the National Science Foundation in 1992 with a 5-year grant. It is now a commercial system that is used both on an individual basis and on a classroom basis to learn many different levels of Mathematics.[4] ALEKS is accessible from any computer with web access and a java-enabled web browser. Students are required to work problems and enter the solution; there are no multiple choice questions associated with the system. Immediately after entering the solution, the student learns whether their solution is correct, and if incorrect, the full solution is one “click” away, providing an immediate feedback loop that is critical in improving algebra skills.

The use of ALEKS in a freshman engineering course was first described by Hampikian, et al., (2006),[5] in work that was motivated by Carpenter and Hanna.[6] Since 2001, the latter researchers have deployed ALEKS as a mandatory aspect of the Calculus I and II instruction at Louisiana Tech University. Their results indicate that strong student use of ALEKS highly correlates with student retention and success in Calculus I. These results are despite the fact that the highest level that ALEKS reaches in mathematics education is Precalculus.

Thus, ALEKS was selected as a primary tool in ENGR 110 with the goal of increasing student success in Precalculus. Students were required from the second week of classes to use ENGR 110 class time to make 4% weekly progress in ALEKS. ENGR 110 met three times a week for 5.5 hours, most of which was used by students working ALEKS, or doing math homework, which was encouraged. In the first six weeks, one of the class hours was used for a weekly freshman seminar, which included general instruction on aspects of the university and adapting to college life. The first several weeks included these concepts: Adapting to College Norms and Values; Classroom Expectations, Getting to Know Your Campus, General Study Skills, and more. The freshman seminar was facilitated by an instructor that normally taught a seminar course that the university routinely offers incoming freshmen, and that has achieved a measure of success in helping students make the transition to university life. However, after approximately six weeks, the course coordinator of the Learning Communities was approached by many ENGR 110 students, who strongly desired to opt out of this aspect of the course, so as to be able to use their ENGR 110 class time to make additional progress in ALEKS. As a result of this, 23 out of the 33 students enrolled in ENGR 110 elected to take what developed to be the "ALEKS Challenge," which required an increase in learning progress (6% progress per week) relative to the original syllabus (4% per week), as well as an increase in learning goal (75% of knowledge space, compared with 65% of knowledge space).

The cooperation of the Mathematics department allowed us to conduct a detailed assessment of the benefits of ALEKS in improving math success among engineering students. ENGR 110 students were embedded in mathematics sections with other students; therefore, we were able to compare the progress of ALEKS students and "nonALEKS" students in the same math sections. Using only the students in ENGR 110, we were able to investigate correlations between important motivational factors and learning styles associated with student success in math. After the first examination, the Mathematics department offered students with failing scores the chance to drop Precalculus and enroll in advanced algebra, a subcomponent of Precalculus. Across the 10 sections of Math 147, a cohort of approximately 32 students enrolled (7 of which were from the group of 33 students that were also enrolled in ENGR 110). Of this cohort, 15 students that would otherwise have certainly failed their first university math course, successfully completed advanced algebra.

There were a total of 37 students enrolled in two sections of ENGR 110. Of these students, 25 students remained enrolled in the two Precalculus sections throughout the semester; and 18 of the 25 took all of the exams and obtained a final numerical grade. These students constituted the "ALEKS" students, who were compared to the "nonALEKS" students in the same two sections of Precalculus. The remaining 12 ENGR 110 students consisted of a group of 7 that elected to switch from Precalculus to advanced algebra, 3 students that were enrolled in different sections of Precalculus, and two that began at lower math levels altogether (and that worked lower levels of ALEKS). All the students continued to use ALEKS in ENGR 110 throughout the semester, no matter what their math level was, and continued to make progress in knowledge space. Although the 12 students were not the focus of the assessment, their progress as students in mathematics will be monitored longitudinally in order to fully assess the tutorial mathematics program (ENGR 110).

Assessment Methods

Student performance was assessed using overall final numerical grade in their math course (Math score). The following two categories were used:

1. ALEKS and non-ALEKS students in the same Precalculus sections;
2. ALEKS students only (including students enrolled in another Math course).

Metrics used in the first category were ALEKS **participation**, ALEKS **success** (defined as meeting either a 65% or 75% ALEKS completion rate, depending upon student-selected option. Students choosing the 75% completion-rate option were excused from an unrelated University activity.) ALEKS completion level (indicated by ALEKS as % of knowledge space, termed ALEKS **score**), total hours worked on ALEKS (**hours**), and average ALEKS completion **rate** (ALEKS score/hours). The Math scores for ALEKS students who attained ALEKS scores, hours, and rate values above the means were compared to the Math scores of non-ALEKS students in each section. For example, 4 students in Precalculus section 1 scored above the mean ALEKS value for ALEKS score. The Math scores for these 4 students were compared to the Math scores of non-ALEKS students in section 1. The Math scores of ALEKS and non-ALEKS students were also compared in each section, as were the Math scores of ALEKS students who met their ALEKS goal. The Independent-Samples T-Test was used for statistical determinations in the first category.

Metrics used in the second category were ALEKS score and ALEKS hours. Motivational orientation and learning strategies were also assessed in the second category, using the Motivated Strategies for Learning Questionnaire (MSLQ).[7] Bivariate Correlation was used for statistical determinations in the second category.

The MSLQ was developed by a team of researchers from the National Center for Research to improve postsecondarytTeaching and learning and the School of Education at the University of Michigan.[7] The MSLQ contains 15 different scales (81 question items in total) that measure college students' motivational orientation and learning strategies. Among the 15 scales, the following 9 scales were used in this study:

1. Value component: Intrinsic goal orientation
2. Value component: Task value
3. Affective component: Test anxiety
4. Cognitive and metacognitive strategies: Elaboration
5. Cognitive and metacognitive strategies: Organization
6. Cognitive and metacognitive strategies: Critical thinking
7. Cognitive and metacognitive strategies: Metacognitive self-regulation
8. Resource management strategies: Time and study environment
9. Resource management strategies: Effort regulation

Thirty-three students who enrolled in ENGR110 completed the MSLQ survey at the end of the class. All students took a Math class (either Precalculus or a lower course) during the same semester, and their final scores were obtained from the Math Department for analysis.

An exit survey with 20 questions was also given to ENGR 110 students to elicit comments about their experiences with ALEKS.

Results

Results for Category 1 students (ALEKS compared to nonALEKS) are shown in Tables 1 through 5. Results for Category 2 students (ALEKS only) are shown in Tables 6 and 7.

Category 1: ALEKS v. nonALEKS [not significant at p<.05 level], Tables 1-5

Table 1: ALEKS **Participation** – Math Score Comparison

Section 001	ALEKS	N	Mean
CLASS SCORE	No	20	83.66
	Yes	6	87.03

Section 002	ALEKS	N	Mean
CLASS SCORE	No	12	59.35
	Yes	12	59.82

Table 2: ALEKS **Success** – Math Score Comparison

Section 001	ALEKS	N	Mean
CLASS SCORE	No	20	83.66
	Yes	5	85.68

Section 002	ALEKS	N	Mean
CLASS SCORE	No	12	59.35
	Yes	7	64.87

Table 3: Above Mean ALEKS **Score** - Math Score Comparison

Section 001	ALEKS	N	Mean
CLASS SCORE	No	20	83.66
	Yes	4	86.83

Section 002	ALEKS	N	Mean
CLASS SCORE	No	12	59.35
	Yes	7	64.87

Table 4: Above Mean ALEKS **Hours** - Math Score Comparison

Section 001	ALEKS	N	Mean
CLASS SCORE	No	20	83.66
	Yes	3	84.60

Section 002	ALEKS	N	Mean
CLASS SCORE	No	12	59.35
	Yes	5	55.40

Table 5: Above Mean ALEKS **Rate**- Math Score Comparison

Section 001	ALEKS	N	Mean
CLASS SCORE	No	20	83.66
	Yes	2	93.65

Section 002	ALEKS	N	Mean
CLASS SCORE	No	12	59.35
	Yes	6	65.07

Category 2 – ALEKS students only

Table 6. Correlations among ALEKS hours, ALEKS scores, and Math scores

		ALEKS hours	*ALEKS Scores*
Math Scores	Pearson's Correlation	.18	.48**

Table 7. Correlations among Math scores, ALEKS hours, and motivation/learning strategies

		Intrinsic Goal Orientation	*Test Anxiety*	*Elaboration*	*Organization*	*Effort Regulation*
ALEKS hours	Pearson's Correlation	-	.45 **	.33 *	.34 *	-
Math Scores	Pearson's Correlation	.36 *	-	-	-	.33 *

* Correlation is significant at the 0.05 level (1-tailed)
** Correlation is significant at the 0.01 level (1-tailed)

Discussion of Results

With one exception, the mean Math scores for all metrics in Category 1 were higher for the ALEKS students than for the nonALEKS students in Precalculus. However, none of these results were significant at the $p<.05$ level, under the assumption of equal variance. This may be due in part to small sample sizes, particularly in section 1. Assistance rendered to some of the ALEKS students during on-line assessment exams by other students is suspected to have increased the variance of the Math Scores among some of the ALEKS students who met their goals and achieved ALEKS Scores higher than mean values.

Table 6 shows that ALEKS scores were strong predictors for Math scores among students in Category 2 (Pearson's Correlation = .48, $p < .01$). This result indicates the potential effectiveness of ALEKS for improving the Math scores of students enrolled in Precalculus and lower-level math courses. However, ALEKS hours were not strong predictors for Math scores among the same students.

Table 7 shows that students in Category 2 who spent more time with ALEKS tended to have higher elaboration learning skills (Pearson's Correlation = .33, $p < .05$) and higher organization learning skills (Pearson's Correlation = .34, $p < .05$), but they also showed higher test anxiety levels (Pearson's Correlation = .45, $p < .01$). Also, students who had higher intrinsic goal levels and better effort regulation skills tended to perform better in their Math classes (Pearson's Correlation = .36, $p < .05$ and Correlation = .33, $p < .05$, respectively). Students' ALEKS scores did not correlate strongly with any motivation and learning skills.

Research shows that test anxiety is usually negatively related to academic performance.[7] Therefore, the positive relationship between test anxiety and Math scores of the students who participated in this study may be seen as anomalous. However, the ALEKS students' high test anxiety may be explained by their Math scores (*Mean* = 64.74, *SD* = 22.03), and by their placement in Precalculus and lower-level math courses, which indicates that many of them may have a history of low achievement in Math.

Intrinsic goal orientation refers to the students' perceptions about the reasons why they participate in a task. Intrinsic goal orientation, compared to extrinsic goal orientation, likely promotes better understanding of the learning subject.[8] This study revealed that students with higher levels of intrinsic goal orientation tend to perform better in Math. The implication of this result is to encourage students to develop curiosity and reasons for learning Math by employing motivationally appealing instructional strategies during instruction, such as providing interesting real-world applications of the Math problems.

Effort regulation is one of the resource management strategies that help students control their effort and attention in the situation where distractions occur and they become unmotivated to learn. Cognitive awareness and control of effort leads to self-monitoring and self-evaluation, which in turn facilitates self-regulatory control behaviors such as persisting, dedicating appropriate time for learning, effort-expanding, and help-seeking when needed.[9] Effective effort regulation skills are important for succeeding in academic settings, as shown in this study: Students with higher levels of effort regulation scored higher in Math whereas low academic achievers would tend to give up early. It is recommended that through early detection of low academic achievers, instructors provide more personal feedback and encouragement to those low achievers to help them increase and sustain their effort regulation skills.

Some observations about student interaction should be noted. The cohort of students that corresponded to section 01 of Math 147 had a very positive classroom experience. In ENGR 110 class, these students cheerfully helped each other solve homework problems, explained difficult concepts in ALEKS to each other, and generally engaged in the class. By contrast, the students from the other cohort, had a distinctly different outlook, and were a very somber class that did not engage nearly as much with each other or with the instructors. This is likely attributable to the stark contrast in the final averages of the two Precalculus classes; section 01 had a mean score for the class of 84.2. In section 01, one student failed, and the remainder received A (13), B (12) and C (5) grades. Section 02, by contrast, had a mean of 51.8. The grade distribution was A (0), B (2), C (3), D (6), F (15), W (2). The ALEKS achievement, as measured by % knowledge space of the two cohorts of students was not consistent with the large disparity in grades corresponding to the two sections of students; section 01 students achieved 67.2% of knowledge space (8.4 standard deviation); section 02 students achieved 63.9% of knowledge space (12.8 standard deviation).

Student comments from the exit survey were almost unanimous in their positive regard for ALEKS used in ENGR 110. For example, about 63% of the students said that ENGR 110 had 'definitely' or 'probably' helped them succeed in Math (42.4% and 21.2%, respectively), about 63% of them said that ENGR 110 was 'very much' or 'somewhat' helpful in increasing confidence in Math (33.3% and 30.3%, respectively), and over 66% of the students said that they found ALEKS to be 'always' or 'often' helpful in learning Math (21.2% and 45.5%, respectively). Students also expressed their positive experiences with the 'Engineering Learning

Community' environment - about 45% of them 'always' or 'often' found their classmates to be helpful in learning Math (18.2% and 27.3%, respectively), and when they have difficulty in solving Math homework, they would seek help from their classmates (45.5%), somewhere else (27.3%) or their Math instructor (15.2%).

Conclusions

Successful learning is produced through reciprocal interactions among learners' self-belief system, their learning behaviors and the learning environment.[10,11] We found that the learning environment provided with ALEKS and the Engineering Learning Community was beneficial in improving the success of ENGR 110 students in Precalculus. However, in future offerings of ENGR 110, although some topics of freshman seminar may still be incorporated, a separate instructor will not be used for this purpose. While not statistically significant, we found the ad hoc student comments regarding their experiences to be encouraging. The continuing longitudinal study will provide a larger sample size and hopefully will provide statistical validation. The effects of ALEKS will be better observed by decoupling ALEKS progress from the ENGR 110 course grade, thus reducing the motivation of students to seek outside assistance in progress assessment exams. We recommend "closed-book" assessments every two weeks that mimic an exam environment (no talking) in order to prevent students from rendering assistance to each other during ALEKS assessments, and also to help students gain experience in Math performance skills. We also feel that larger class sections of ENGR 110 would improve the statistical significance of our metrics.

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