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Enhancing Precalculus Curricula with E-Learning: Implementation and Assessment

Janet Callahan
Boise State University

Seung Youn Chyung
Boise State University

Joanna Guild
Boise State University

William Clement
Boise State University

Joe Guarino
Boise State University

See next page for additional authors

Authors
Janet Callahan, Seung Youn Chyung, Joanna Guild, William Clement, Joe Guarino, Doug Bullock, and Cheryl Schrader

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Janet Callahan, Boise State University

Janet M. Callahan is Associate Dean for Academic Affairs at Boise State University. She received a Ph.D. in Materials Science, a M.S. in Metallurgy and a B.S. in Chemical Engineering from the University of Connecticut. Her current research interests include freshman engineering programs, recruitment and retention issues in engineering, biomedical device development and the development and characterization of biomaterials.

Seung Youn Chyung, Boise State University

Yonnie Chyung is Associate Professor in the Department of Instructional and Performance Technology at Boise State University. She received her Doctor of Education degree in Instructional Technology from Texas Tech University, and her Master's degree in Curriculum and Instruction, with a specialization in Computer-based Education, from Southern Illinois University, Carbondale, IL. Her research interests have been focused on the development of self-regulated learning strategies for adult learners, and online teaching and learning. She is currently conducting research on retention issues in online distance education.

Joanna Guild, Boise State University

Joanna Guild is Special Lecturer for the Department of Mathematics at Boise State University. She obtained her M.S. in Mathematics from Boise State University and a B.A. in Mathematics from Kenyon College.

William Clement, Boise State University

William P. Clement is Associate Research Professor at the Center for Geophysical Investigation of the Shallow Subsurface at Boise State University. His research interests include using near-surface geophysical methods such as Ground Penetrating Radar reflection data and cross-hole GPR tomography to better understand processes in the shallow subsurface.

Joe Guarino, Boise State University

Joe Guarino is a Professor in the Mechanical and Biomedical Engineering Department at Boise State University. His research interests include simulation modeling for engineering education, vibrations and acoustics.

Doug Bullock, Boise State University

Doug Bullock is Chair and Associate Professor of Mathematics at Boise State University. His research interests are quantum topology, quantum algebra and representation theory, with particular emphasis on applications to knot theory and the topology of 3-manifolds.

Cheryl Schrader, Boise State University

Cheryl B. Schrader is Dean of the College of Engineering and Professor of Electrical and Computer Engineering at Boise State University. Dean Schrader has an extensive record of publications and sponsored research in the systems, control and engineering education fields. She received the 2005 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring from the White House for an enduring, strong and personal commitment to underrepresented engineering students and faculty.

Enhancing Precalculus Curricula with E-Learning: Implementation and Assessment

Abstract

During Fall semester of 2007, a semester-long, quasi-experimental study was conducted at Boise State University to investigate the effectiveness of a systematically sequenced and managed, self-paced e-learning activity on improving students' academic performance and motivation. A total of 125 students enrolled in 3 different sections of a Precalculus class participated in the study. The e-learning activity was implemented in 2 of the 3 sections as a required homework assignment. Students enrolled in one of the 2 selected sections were all engineering majors. The 3rd section was a control group that did not use the e-learning activity. A pre-test, measuring students' entry-knowledge levels, was administered at the beginning of the semester, and a post-test was administered at the end of the semester. Students' learning styles were measured with the Gregorc Style Delineator™. Then, the relationships among the students' learning styles, their academic performance, and self-regulated studying behaviors such as the number of hours they spent on weekly e-learning homework assignments were investigated. This study revealed that using an e-learning activity as a homework assignment improved students' knowledge in Precalculus about the same as did traditional homework that was collected, graded and returned daily. Moreover, we found that different types of learning styles were associated with different degrees of knowledge improvement in Precalculus. Several recommendations on instructional strategies related to students' learning styles are discussed.

Introduction

To facilitate learning processes and to help students produce successful learning, especially during the early years of their study, educators often seek innovative instructional technology. One such technology is e-learning. Presently, e-learning is already deeply integrated into school curricula to motivate students and facilitate learning. Numerous studies have revealed the benefits of implementing self-paced e-learning strategies in traditional curricula for improving critical learning variables such as motivation, self-efficacy, goal-orientation, satisfaction, and persistence.[1] Especially, there has been a fair amount of acceptance and practice among the community of science and engineering education community that traditional teaching can be greatly benefited by incorporating e-learning strategies.[2-6] Leading academic organizations such as the Sloan Consortium also advocate that incorporating online learning strategies into the engineering curricula can augment some of the ABET engineering competencies.[2]

E-learning is also ideal for individualized learning. In contrast to lecture-based classroom learning, computer-based learning programs allow students to adjust the pace, sequence and method of learning to better fit their learning behavior and needs. A study by Yoshioka, Nishizawa, and Tsukamoto[7] revealed that individualized exercises improved calculating skills of engineering students in a fundamental mathematics class. A significant advantage associated with e-learning is that students can learn at their own convenience and are less dependent on the instruction given in class, making it advantageous for nontraditional students that may find it difficult to attend class on a daily basis.

For example, ALEKS (Assessment and LEarning in Knowledge Spaces) is a web-based e-learning program.[8] It provides a systematically sequenced and managed, self-paced e-learning activity, designed to help improve math skills. ALEKS breaks down the Precalculus curriculum into topics, or problem types, that students must work through in order to master the material and complete the course. It is possible to customize a course to include only desired topics; this course was customized and consisted of 178 topics from a list of about 250 total Precalculus topics.

Each student takes an initial assessment in ALEKS to determine which topics he or she has already mastered and which topics he or she is ready to learn. Following this initial assessment, the students begin working in “Learning Mode”. Here the students are presented with a list of topics selected by the web based engine that, based on their assessment, they have the prerequisite knowledge to learn. A student then picks a topic to work on and is given several problems from that topic to practice. When the student types in an answer (very few problems are multiple choice), ALEKS provides immediate feedback concerning the correctness of the given response. If the student has trouble with a certain topic, there is always a complete explanation available for any problem. When the student has answered a sufficient number of problems from the chosen topic correctly, that topic is added to the student’s Knowledge State and the student can move on to a new topic. As the student masters the topics in this manner, more complex topics become available for him or her to work through, with the end goal being complete mastery of the Precalculus curriculum.

In addition to allowing students to work problems in Learning Mode, ALEKS periodically reassesses the students. These 20-30 question assessments occur after a student has completed 20 new topics or spent 10 hours logged into ALEKS. If a student answers a question incorrectly during an assessment, that topic is removed from the student’s Knowledge State and the student must re-demonstrate mastery of that topic in Learning Mode. This provides an excellent way for the students to review and to reinforce topics from throughout the semester, as well as to ensure that the students retain the topics they have learned.

ALEKS provides a personalized, time-efficient environment in which each student is able to work through the Precalculus curriculum at his or her own pace. If a student begins the course already having mastered certain topics, and demonstrates this mastery on an assessment, ALEKS does not require the student to work through problems from that type. Rather, the student is free to move on and spend time working on topics that they have not yet mastered. Many students informally commented throughout the semester that they appreciated this feature of ALEKS.

Working problems using ALEKS also has significant advantages over doing traditional “pencil and paper” homework. First, the student receives immediate feedback as to whether he or she is doing the problem correctly. While this is true for almost any e-learning strategy, ALEKS has the additional advantage that the student is required to work several problems from each topic correctly before that topic is considered mastered and the student is able to move on. Therefore, if a student works a problem incorrectly, that student must go back through his or her work and not only find the mistake, but correct the mistake and answer the problem correctly. This is not only a very useful process for students to practice, but a process that is very hard to require of students in a more traditional classroom setting with handwritten and hand-graded homework. Also, a significant advantage to using progress in ALEKS as homework in lieu of written homework assignments, is that it significantly reduces the load on the instructor while still providing critically needed feedback and student accountability.

When incorporating e-learning into their curricula, another important element that educators should take into account is learners' characteristics such as pre-knowledge levels, personalities, or learning styles. There are various instruments that measure people's different cognitive tendencies or learning styles, including the Gregorc Style Delineator™. The Style Delineator measures four qualities of concreteness, abstraction, sequence, and randomness in people's perception toward, and ordering of, their world.[9] As shown in Table 1, dominant learning styles are identified with one of four style types: concrete-sequential (CS), abstract-sequential (AS), concrete-random (CR), and abstract-random (AR). Every individual has the ability to orient himself or herself toward all four styles. However, people tend to have strong orientation toward one or two, or sometimes even three, dominant style(s). The Style Delineator reveals a score for each style type, identifying the dominant learning style(s) among the 4 types. For example, a person might score 39, 19, 26, and 16 for CS, AS, CR, and AR, respectively, resulting in a dominant learning style of CS.

Table 1. Four Learning Style Types Identified by Gregorc Style Delineator.

	Concrete	**Abstract**
Sequential	CS	AS
Random	CR	AR

Gregorc explains that people with different dominant styles tend to have different views of their world and exhibit different characteristics. People with dominant CS styles view and approach their experiences in an ordered, sequential, and one-dimensional manner. They tend to follow a 'train of thought' with a clear beginning and a clear end, and they excel in making, gathering, and controlling objects. People with dominant AS styles also approach their experiences in an ordered and sequential manner, but their approach is two-dimensional, which is analogous to a tree with multiple branches. They value knowledge, and they are willing to gain knowledge for the sake of knowledge. People with dominant CR styles use intuition and instinct and are concerned more with ideals than with materials, and more with attitudes than with facts. They pay attention to applications, methods and processes of knowledge. People with dominant AR styles behave in a non-linear and multi-dimensional manner, their thinking processes are anchored in feelings, and they concentrate their energies on social relationships.

However, no one possesses one 'pure' style; every individual is capable of orienting himself or herself toward all four styles. Because learners tend to prefer learning environments that support and stimulate their dominant style, understanding learning styles helps educators evaluate and modify their instructional methods and strategies.

We conducted a semester-long study in fall of 2007 to investigate the effectiveness of using the e-learning program, ALEKS, on improving academic performance and motivation of students in Precalculus classes. We also investigated the relationships between the students' learning styles, their degree of improved knowledge in Precalculus, and their self-regulated studying behaviors while using ALEKS.

Method

Research Questions

This study aims to answer the following questions:

1. Does the use of an e-learning activity (ALEKS) have a significant effect on improving students' knowledge in Precalculus?
2. Are there strong relationships between students' learning styles and the degree of improved knowledge in Precalculus?
3. Are there strong relationships between students' self-regulative behaviors (the total time spent and the level of Math skills mastered while using ALEKS) and the degree of improved knowledge in Precalculus?
4. How do engineering students perceive the use of ALEKS in their Precalculus class as a supplementary learning activity?

The first three research questions were answered by testing the following null hypotheses, and the last research question was investigated by using descriptive statistics and qualitative data:

1. The use of an e-learning activity (ALEKS) has no significant effect on improving students' knowledge in Precalculus.
2. There are no strong relationships between students' learning styles and the degree of improved knowledge in Precalculus.
3. There are no strong relationships between students' self-regulative behaviors (the total time spent and the level of Math skills mastered while using ALEKS) and the degree of improved knowledge in Precalculus.

Research Design and Participants

A nonequivalent control group design was used in this quasi-experimental study. A total of 129 students enrolled in 3 sections of MATH 147 Precalculus class in the fall semester of 2007, but 4 students withdrew during the semester. Therefore, a total of 125 students participated in this study. Among them, 88 students (70.40%) were male and 38 students (29.60%) were female. The students in the 1st section of the class (N = 48) were all engineering majors and were taught by a male instructor. The students in the 2nd section (N = 40) and the 3rd section (N = 37) were a mixture of various majors across the disciplines (with 6 and 9 of them being engineering majors in sections 2 and 3, respectively). Both the 2nd and 3rd sections were taught by the same female instructor. All 3 sections of the class were held for 50 minutes, 5 times a week, Monday through Friday.

Section 1 and section 2 were the experimental group which participated in an e-learning activity (the use of ALEKS) as a weekly homework assignment. We verified that section 1 and section 2 were not significantly different in terms of their pre-test scores. Section 3 was a control group in which an e-learning activity was not used. Table 2 describes the different conditions of the groups.

All three sections moved through the material according to the same schedule. The schedule was devised in a way that allotted approximately 10 classes for the first 79 ALEKS topics (chiefly review from intermediate algebra topics), and then moved through the remaining material (99 topics in ALEKS) at an average rate of about 1.6 topics per class (8 topics per week). Class grades were comprised for all three sections as follows: homework was 30% of the grade; each of five exams was worth 11%, and the final comprehensive exam was 15% of the final grade. The homework grade in the e-learning groups (sections 1 and 2) was set according to the percentage of the assigned material that was completed, with 8 deadlines at approximately 2 week intervals throughout the semester. These dates corresponded to the completion of the appropriate chapter in the assigned textbook. Meanwhile, in section 3, homework was assigned, collected and graded by the instructor on a daily basis.

Table 2. Experimental and Control Groups.

		Student					E-
Group	**Section**	**Major**	**Male**	**Female**	**Total**	**Instructor**	**learning**
Experimental	1	Engineering	44	4	48	Instructor 1	ALEKS
	2	Various	23	17	40	Instructor 2	ALEKS
	Subtotal		67	21	88		
Control	3	Various	21	16	37	Instructor 2	None
	Total		88 (70.40%)	37 (29.60%)	125 (100%)		

Instruments and Procedures

Pre- and Post-Knowledge Tests: A pre-test was administered at the beginning of the semester to measure students' entry-knowledge levels in Precalculus, and a post-test at the end of the semester. Eleven identical questions were included in both tests, and 105 students completed both tests (20 missing data when excluding missing cases).

Gregorc Style Delineator: To assess students' learning styles, the Gregorc Style Delineator was administered during the semester, and 117 students completed the instrument (8 missing data).

E-Learning Activity (ALEKS): Students in the experimental group (section 1 and section 2) were asked to use ALEKS as a homework assignment. The system kept track of the total time individual students spent with ALEKS and the level of Math skills they mastered in ALEKS, and 81 sets of data were retrieved from the system after the semester was over (7 missing data when excluding missing cases).

Exit Survey: At the end of the semester, the engineering majors (section 1) submitted an exit survey with 21 questions. The exit survey measured students' perceptions toward the use of ALEKS and their motivation and confidence levels in Math skills for continuing their study in engineering.

Data Analysis: The data were analyzed using SPSS 15.0 for Windows (2006) [10]. Statistical procedures used for inferential statistics include a Wilcoxon signed ranks test, a Mann-Whitney *U* test, and Pearson correlation coefficients.[11, 12]

Results

Students' Overall Learning of Precalculus

The possible range of the pre-test and post-test scores was zero to 100. The pre-test scores of all entire participants ranged from 0 to 47 (M = 9.86, SD = 8.25), and the post-test scores ranged from 14 to 100 (M = 70.27, SD = 18.25) (see Table 3). The pre-test scores and post-test scores were fairly skewed (Skewness = 1.49 and -1.06, respectively). The difference between individual students' pre-test scores and their post-test scores is the degree of improved knowledge (i.e., learning) (M = 60.40, SD = 17.09). The normality test on the knowledge improvement scores showed that its normality assumption was not met (Shapiro-Wilk = .95, $p <$ .00). Therefore, a nonparametric Wilcoxon signed ranks test was conducted to reveal whether or not the difference between the pre-test scores and the post-test scores was significant.[11] The test revealed the difference was significant at a .01 level, Z (104) = -8.89, $p <$ .00, indicating that overall, students significantly improved their knowledge in Precalculu*s* during the course of a semester.

Group Differences in Knowledge Improvement in Precalculus

The mean values of the pre-test scores and post-test scores for the experimental group (sections 1 and 2 combined) were 8.58 (SD = 7.35) and 67.82 (SD = 19.72), respectively; therefore, the average degree of improved knowledge was 59.23 (SD = 18.04). The mean values of the pre-test scores and post-test scores for the control group were 12.78 (SD = 9.48) and 75.87 (SD = 12.95), respectively; therefore, the average degree of improved knowledge was 63.09 (SD = 14.62).

Table 3. Descriptive Statistics for Pre-Test and Post-Test Scores Between Groups.

		Pre-Test	Post-Test	Difference
Experimental	*M*	8.58	67.82	59.23
($N = 73$)	*SD*	7.35	19.72	18.04
Control	*M*	12.78	75.87	63.09
($N = 32$)	*SD*	9.48	12.95	14.62
Total	*M*	9.86	70.27	60.40
($N = 105$)	*SD*	8.25	18.25	17.09

Effects of ALEKS on Knowledge Improvement in Precalculus

The first null hypothesis was: The use of an e-learning activity (ALEKS) has no significant effect on improving students' knowledge in Precalculus. As shown in Table 3, the control group produced a higher average post-test score than the experimental group did. However, the control group's pre-test scores were also higher than the experimental group's pre-test scores. Because the assumptions of normality were not met for the pre-test, post-test, and degree of improved knowledge variables, we conducted multiple Mann-Whitney *U* tests to examine the differences in pre-test scores, post-test scores, and knowledge improvement between the two nonparametric independent samples.

The *U* tests revealed significant differences in pre-test scores and post-test scores between the experimental and control groups, $Z = -2.36$, $p < .05$, and $Z = -2.00$, $p < .05$, respectively. However, the degree of knowledge improvement between the two groups was not significantly different, $Z = -.58$, $p > .05$ (see Table 4). Therefore, the first hypothesis was not rejected. There was no significant difference in the degree of knowledge improvement between section 1 and section 2 (i.e., engineering majors vs. non-engineering majors) of the experimental group either, $Z = -1.32$, $p > .05$.

Table 4. Results of Independent-Samples Mann-Whitney *U* Tests.

Observation	*Mann-Whitney U*	Z	Sig. (2-tailed)
Pre-test	829.00	-2.36	.01
Post-test	880.00	-2.00	.04
Knowledge improvement	1083.50	-.58	.55

Learning Styles and Knowledge Improvement in Precalculus

The most frequently identified dominant learning style among the students was concrete-sequential (CS); 60 students (51.79%) scored CS as their dominant style. Abstract-random (AR) was the most frequently identified weakest learning style among the students; 46 students (39.31%) scored AR as their weakest style.

Although the normality assumption for the degree of knowledge improvement variable was not met, the normality assumptions for the four sets of learning style scores were not violated. Therefore, Pearson correlation coefficients were computed. To minimize the chances of making a Type I error across the 10 correlations, the Bonferroni approach was used and a p value of less than .005 (.05/10 = .005) was considered for significance.[12] An interesting finding from the correlational analyses was that the scores of the two sequential types (CS and AS) and the scores of the two random types (CR and AR) among students were negatively correlated at the .005 significant level (see Table 5). This implies that when students have a strong *sequential* tendency or preference in a concrete or abstract manner (CS or AS), they tend to exhibit a weak *random* tendency or preference in those manners (CR or AR).

The second null hypothesis was: There are no strong relationships between students' learning styles and the degree of improved knowledge in Precalculus. This null hypothesis was rejected as we found that the more AS tendency or preference students had, the more they increased their knowledge of Precalculus (Pearson's $r = .28$, $p < .005$). On the other hand, when using a p value of .05 as the significant level by taking a risk of making a Type I error, it was found out that the more CR tendency or preference students had, the less they increased their knowledge of Precalculus during the course (Pearson's $r = -.24$, $p < .05$). However, as explained above, the possible Type I error when using a p value of .05 across 10 correlations should be noted, and this result should be interpreted with caution. Also, it is important that these results indicate correlation, not causation; therefore, it should not be interpreted as if the characteristics of AS and CR *caused* the observed results.

Table 5. Correlations Matrix among Learning Styles and Degree of Knowledge Improvement.

		CS	**AS**	**CR**	**AR**	**Knowledge Improvement**
Pearson Correlation	CS	-	.11	-.59**	-.51**	.13
	AS	-	-	-.36**	-.59**	.28**
	CR	-	-	-	.02	-.24*
	AR	-	-	-	-	-.15

** Correlation is significant at the 0.005 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Self-Regulative Behaviors While Using ALEKS and Knowledge Improvement in Precalculus

The third null hypothesis was: There are no strong relationships between students' self-regulative behaviors (the total time spent and the level of Math skills mastered while using ALEKS) and the degree of improved knowledge in Precalculus. To test the hypothesis, we analyzed the total time (measured in hours) students spent with ALEKS and the level of Math skills they mastered in ALEKS obtained from the experimental group (section 1 and section 2). See Table 6.

Table 6. Descriptive Statistics for Total Time Spent and Mastery Level Achieved in ALEKS.

		Total Time Spent [b]	**Math Skills Mastered**
Section 1	*M*	115.69	88.07
($N = 41$)[a]	*SD*	39.68	11.71
Section 2	*M*	67.59	85.03
($N = 40$)	*SD*	36.00	17.94
Total	*M*	91.64	86.55
($N = 81$)	*SD*	44.77	15.09

[a] 7 missing cases when excluding missing cases listwise
[b] measured in hours

The normality assumptions for all three variables (total time spent, mastery level, and degree of knowledge improvement) were not met; therefore, Spearman's rho, a nonparametric equivalent of the Pearson correlation coefficient, was calculated. The results showed that the level of Math skills mastered in ALEKS and the degree of improved knowledge were significantly correlated at a .01 level, but the total time spent with ALEKS and the degree of improved knowledge were not (see Table 7).

Table 7. Correlations Matrix between Learning with ALEKS and Degree of Knowledge Improvement.

		Total Time Spent	**Mastery Level**	**Knowledge Improvement**
Spearman's rho	Total Time Spent	-	.03	-.09
	Mastery Level	-	-	.62**
	Learning	-	-	-

** Correlation is significant at the 0.01 level (2-tailed).
(Listwise $N = 73$)

Engineering Students' Perceptions toward the Use of ALEKS

The fourth research question was: How do engineering students perceive the use of ALEKS in their Precalculus class as a supplementary learning activity? The exit survey revealed that students thought that using ALEKS as a supplementary learning activity helped them to learn Math ($M = 5.5$ on a scale of 1 to 7 when 7 is the highest score). Figure 1 presents the frequency of students' responses to the statement "ALEKS helped me learn Math" on a 7-point scale. The students who rated the usefulness of ALEKS as low mentioned that they did not like its highly structured and controlled format. On the other hand, the students who rated the usefulness of ALEKS as high commented that they liked the nature of self-paced learning and the feedback on their learning progress provided by the system.

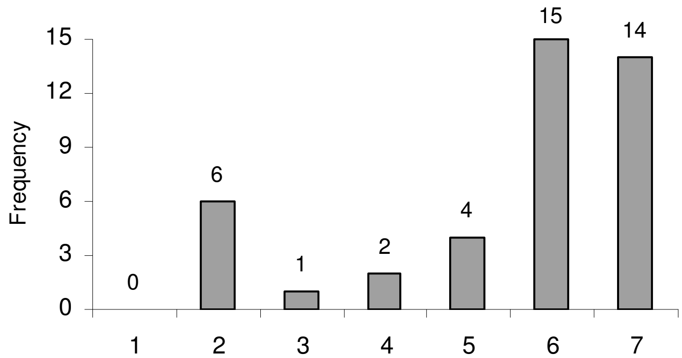

Figure 1. Frequency of Responses to Statement "ALEKS helped me learn Math."

Another question in the survey measured the engineering students' confidence levels about their Math preparation for calculus; the average score was 5.36 on a scale of 1 to 7, where 7 is the highest score. The data were negatively skewed (Skewness = -1.08, see Figure 2). No significant correlations were found between the engineering students' learning styles and their perceptions on the usefulness of ALEKS or their confidence levels in Math preparation for Calculus.

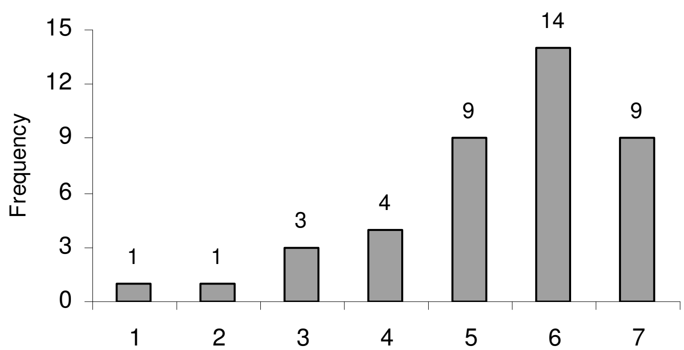

Figure 2. Frequency of Responses to Statement "I am confident about my math preparation for calculus."

Some other results are qualitative. The instructor for sections 2 and 3 indicated that it felt as though she was teaching two different classes. She remarked that the ALEKS material seemed easier, and that there seemed to be less material to cover. Also, she noted less attendance in the ALEKS section, with ½ to ⅔ of the class attending section 2, and with ⅔ to ¾ of the class attending section 3 (no ALEKS). She also noted that the ALEKS section required about five hours less grading than the non-ALEKS section. The instructor for section 1 also reported low attendance on a daily basis. This raises an interesting question -- to what degree can the use of

ALEKS can compensate for the absence of classroom learning? It should be noted that section 3 had written homework collected daily, which promoted attendance. Sections 1 and 2 did not have anything collected daily. Thus, the control group in this study (section 3) consisted of "best practices" in terms of mathematics instruction. A more closely matched control group would have only collected and graded homework about once every two weeks to coincide with the deadlines for student achievement in ALEKS. One would predict such a control group to be less successful in terms of overall mathematics learning than this "best practices" control group was. To investigate these new research questions, future research might be conducted to correlate students' attendance rates, their use of ALEKS, homework due dates and their academic performance.

Conclusions

This study found that using an e-learning strategy (ALEKS) as a homework assignment improved students' knowledge in Precalculus about the same as traditional homework that was collected, graded and returned daily. Based on the positive results that instructors at the university had had with ALEKS in the past,[13,14] it was somewhat surprising that the experimental (ALEKS) group did not outperform the control group. As the study was quasi-experimental, though, some threats to internal and external validity could not be effectively controlled, and conclusions from the study are necessarily guarded -- with the use of a convenience sample instead of random selection and random assignment, other factors in addition to the use of the e-learning activity could have influenced the results.

Findings of this study support the notion that a self-paced e-learning system can be effectively used as a supplementary learning activity. For example, a closer look at the students' self-regulative behaviors while using ALEKS revealed that the level of Math knowledge mastered in ALEKS was significantly correlated with the level of improved knowledge in Precalculus measured by the gap between a pre-test and a post-test. This finding is somewhat expected, as both results indicate students' improved knowledge in Math (therefore, the results are correlated). However, helpful implications can be drawn from this finding: First, instructors can rely on ALEKS as a homework engine that provides students with timely, reliable feedback while maintaining student accountability to accomplish the homework goals. For instructors that grade daily homework assignments, this has a profound impact on instructor time, freeing time that would have been otherwise allocated to grading of homework. Second, instructors can monitor students' use of ALEKS to detect low-level performers, and provide personal feedback and additional guidance. In other words, the use of a self-paced e-learning activity provides instructors with data and opportunities that enable them to direct their time and attention to individual students who need individualized feedback. It also makes effective use of in-class instruction while reducing the grading burden.

Another interesting finding was that the more AS type of learning style students had, the more amount of knowledge in Precalculus they gained. However, this is not too surprising, since the characteristics of AS include a high level of aptitude in abstract thinking and problem solving such as Math or Music. Instead, more attention should be paid to the group(s) of students whose learning styles are negatively correlated with their performance in Math. For example, this study indicates the possibility that the more CR tendency or preference students have, the less amount of knowledge in Precalculus they gained during the course, compared to their AS counterparts. Although this study is unable to support generalizablity of this finding, a reasonable recommendation is to provide students in Math classes, especially those with a strong CR tendency, with more ‘concrete examples’ of abstract Math problems and learning guidance for following step-by-step, sequential learning processes when solving problems (e.g., a job aid, a checklist, or a workbook).

Future Work:

The e-learning strategy, ALEKS, has now been used at Boise State University for three years.[13,14] As a result of this, it has been observed by several mathematics instructors at Boise State University that students that have used ALEKS in Precalculus, do very well in subsequent mathematics courses. One instructor that volunteered to participate in an ongoing study observed, “I had a student [in fall, 2006] who was struggling with Precalculus due to deficits in prerequisite material. The student started working with ALEKS as part of course work for a different class, [an engineering class] and I noticed within a few weeks that the number of errors the student made was decreasing. Having drilled on basic skills, the student was able to focus more on the Precalculus material, instead of being lost in the "basic algebra" steps. This student was ultimately successful in Precalculus, and I attributed that success, at least in part, to work on ALEKS.” We postulate that an important outcome of using ALEKS that occurs during Precalculus throughout the semester, is the repair of prerequisite skills. To date, we have not quantified this by measuring prererequisite knowledge for student participants. Future work will measure the extent of prerequisite knowledge at the beginning and end of the course, as the hierarchical nature of the content in ALEKS forces students to exhibit mastery of prerequisite knowledge before learning new material. Longitudinal studies are also underway to quantify the long term effects of this e-learning strategy on student success as they progress through the calculus sequences.

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