AC 2009-1873: IMPROVING STUDENTS' LEARNING IN PRECALCULUS WITH E-LEARNING ACTIVITIES AND THROUGH ANALYSES OF STUDENTS' LEARNING STYLES AND MOTIVATIONAL CHARACTERISTICS

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Improving Students' Learning in Precalculus with E-Learning Activities and through Analyses of Student Learning Styles and Motivational Characteristics

Abstract

During the spring semester of 2008, a quasi-experimental study with 138 students who were enrolled in 4 sections of an undergraduate Precalculus class was conducted. The study investigated (1) the effectiveness of using a systematically sequenced and managed, self-paced e-learning program, ALEKS, on academic performance of students with different learning styles, and (2) the relationship among the students' dominant learning styles, motivational characteristics, and overall performance in the Precalculus class. Students in the experimental group, consisting of 2 of the 4 sections of the course, were assigned to complete ALEKS as homework assignments throughout the semester. Students in the control group, consisting of the other 2 sections of the course, completed a series of traditional paper-and-pencil homework assignments instead. Students' dominant learning styles were measured by Gregorc Style Delineator™. Their motivational orientations and learning strategies were measured with the Motivated Strategies for Learning Questionnaire. A pre-test and a post-test, measuring students' entry- and exit-knowledge levels in Precalculus, were administered in both experimental and control groups at the beginning and at the end of the semester. This study revealed that *sequential-type* students who used ALEKS outperformed *sequential-type* students who completed handout homework assignments and *random-type* students who used ALEKS or handout homework assignments by one letter grade, although this difference was not statistically significant. Several instructional implications related to students' learning styles, motivational characteristics, and academic performance are discussed. Especially, students with a dominant abstract-random style may need more tailored learning support to be more successful in a Precalculus class.

Theoretical Frameworks

Effective Delivery Media and Methods: E-Learning vs. Traditional

Computer technology has been a paradigm-shifting agent in education since the first computer generation of mainframes during the 1960s and 1970s, and throughout the second generation of desktop computers and the third generation of the Internet and the World Wide Web during the 1980s and 1990s.[1] E-learning is especially ideal for individualized instruction. In contrast to one-to-many classroom learning, web technologies can help adjust the pace, sequence, and method of instruction to better fit each individual student's learning behavior and needs. Presently, e-learning is deeply integrated into school curricula to facilitate learning,[2] and a fair amount of literature discusses that traditional science, technology, engineering and math (STEM) education can be greatly benefited by incorporating e-learning strategies.[3, 4, 5, 6, 7]

One such e-learning program available in STEM education is ALEKS (Assessment and LEarning in Knowledge Spaces).[8] This web-based program provides a systematically sequenced and managed, self-paced environment, designed to help students improve Math skills. In

ALEKS, a variety of different mathematics levels, or courses can be selected, and within each course, the curriculum can be customized through selecting/deselecting certain topics. This research is focused on the Precalculus curriculum, and consisted of 181 topics in all. Students must successfully work through the topics in order to master the content. At any given time, a variety of topics may be selected to be learned by the student; however, each topic has a set of prerequisite topics that must be mastered before it may be worked on. Thus, for example, a student may not proceed to learn a rather complicated trigonometry topic until various prerequisite algebra topics within the Precalculus course are mastered. ALEKS provides immediate feedback concerning the correctness of the student's response (see Figure 1). It also provides elaborated explanations for any problem. As the student masters the topics, the data are added to the ALEKS MyPie, which presents a summary of the student's current performance level and offers more complex topics available for him or her to work through, with the end goal being mastery learning of Precalculus (see Figure 2 and Figure 3).

Using an e-learning program such as ALEKS for practicing Math skills implies potentially significant advantages over using traditional "pencil and paper" homework assignments. First, the student immediately receives diagnosed feedback as to whether he or she is doing the problem correctly. Although delayed feedback may be appropriate in certain context because it allows students to have sufficient time to solve problems on their own which may in turn increase retention of the information,[9] it is often important to provide immediate feedback to students who are working on a series of drill-and-practice type Math problems so that they are able to master each topic before they move on.

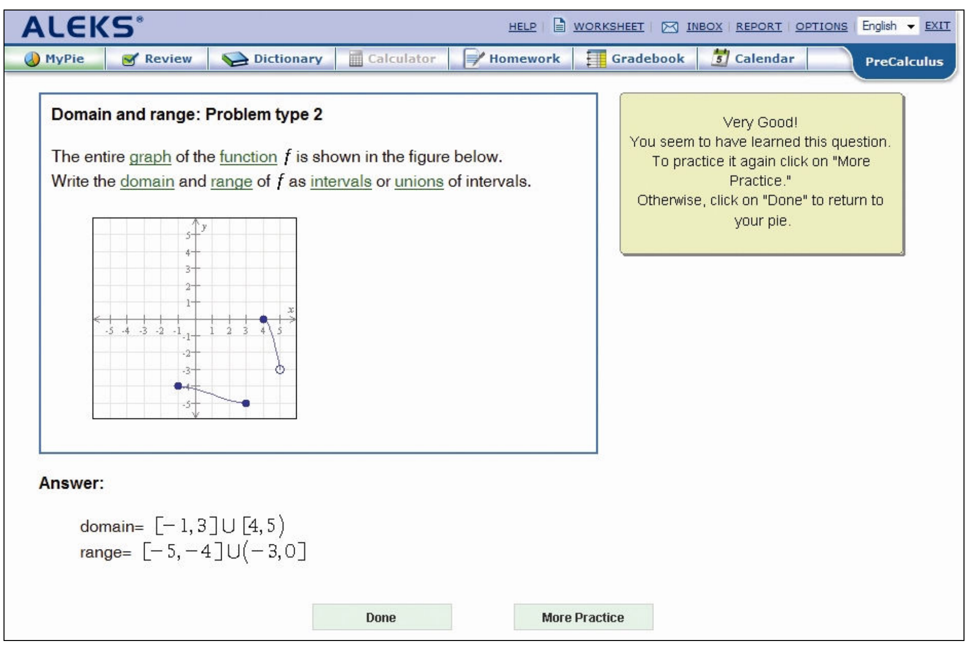

Figure 1. A screen shot of the Learning Mode in ALEKS. [Note: ALEKS product screen shot reprinted with permission from ALEKS Corporation.]

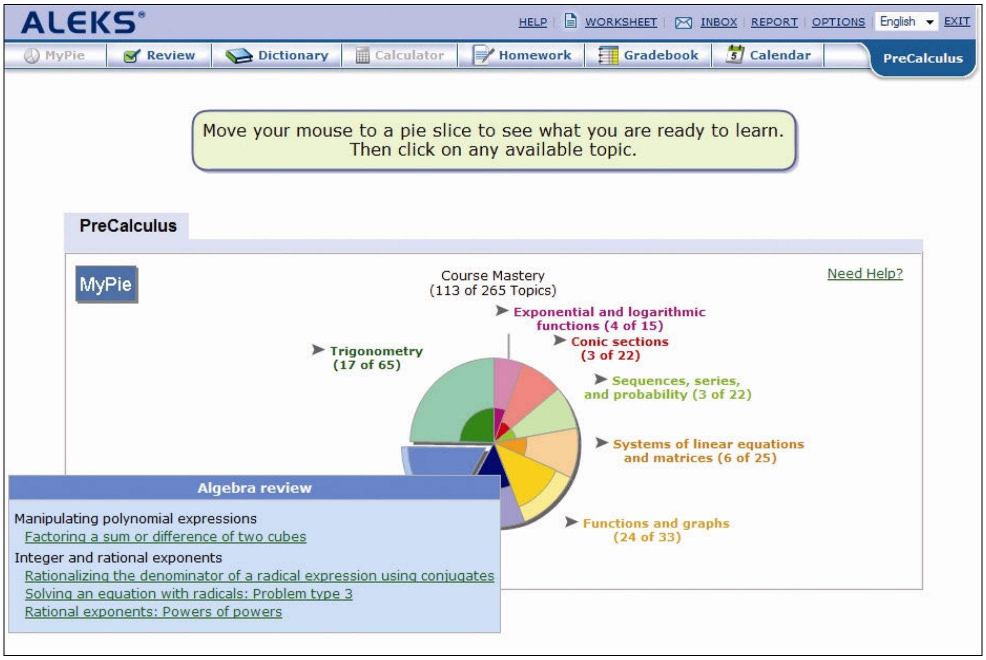

Figure 2. A screen shot of MyPie in ALEKS: The darkened portion of each pie slice represents the topics that the student has mastered and the lighter portion represents what the student has yet to learn. [Note: ALEKS product screen shot reprinted with permission from ALEKS Corporation.]

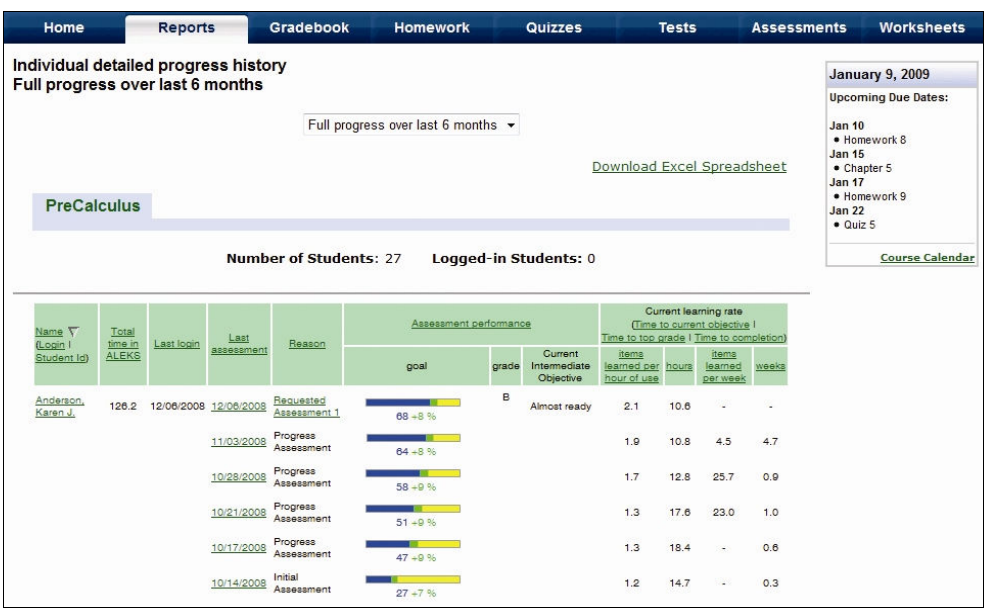

Figure 3. A screen shot of Learning Progress in ALEKS. [Note: ALEKS product screen shot reprinted with permission from ALEKS Corporation.]

Using a program such as ALEKS as homework in lieu of a series of written homework assignments can also reduce the load on the instructors, allowing them to spend more time on other responsibilities such as curriculum improvement, student advising, and professional development. Therefore, it is important to investigate whether an e-learning program such as ALEKS is more effective than, or at least as effective as, traditional pencil and paper homework assignment on helping students improve Math skills.

Relationship between Learning Styles and Academic Performance

Individual students in the same classroom may have different learning experiences due to their characteristics such as learning styles. For example, some students may learn information in a sequential manner more effectively while others tend to approach new information in a more random fashion. Therefore, educators should take into account such characteristics of learners in order to deliver instruction with more effective media and methods for individual students.

A well-known instrument for measuring learning styles is 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.[10] Perceptual abilities are the ways through which people obtain information – in a concrete or abstract way. Ordering abilities are ways in which people organize information – in a sequential or random way. The instrument identifies degrees of abilities with four style types: concrete sequential (CS), abstract sequential (AS), concrete random (CR), and abstract random (AR) (see Table 1). Every individual is believed to be capable of orienting himself or herself toward all four styles; however, people tend to have strong orientation toward one or two, which are viewed as their dominant styles.

Although no one particular learning style is better than another, research has shown strong correlation between dominant learning styles and academic performance in certain learning subjects. Especially, the sequential-random dimension is shown to be a stronger predictor than the concrete-abstract dimension in many areas including STEM.[11] For example, research has revealed that sequential learners perform significantly better than random learners in computer application courses[12] and other Science and Math-related courses, while random learners excel in Fine Arts courses.[13]

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

Sequential (S)		**Random (R)**	
Concrete (C)	**Abstract (A)**	**Concrete (C)**	**Abstract (A)**
Concrete-Sequential (CS)	Abstract-Sequential (AS)	Concrete-Random (CR)	Abstract-Random (AR)

Motivational Orientations and Learning Strategies

In addition to learning styles, students' motivational orientations and learning strategies that they use also likely influence their learning processes. These characteristics can be measured with the Motivated Strategies for Learning Questionnaire (MSLQ), which was developed by a group of researchers in the University of Michigan in the early 1990s.[14] The instrument is intended to measure motivational orientations college students exhibit and learning strategies they use in a college course. The complete MSLQ contains 15 sub-scales, including 6 sub-scales for motivational orientations and 9 sub-scales for learning strategies (see Table 2).

The MSLQ has been used in research to help understand the nature of learner motivation and use of learning strategies in various subject areas such as statistics, chemistry, technology, social studies, and physical education.[15] Research has shown that learner characteristics measured by the MSLQ have strong associations with their self-regulative learning processes and academic performance. Based on research conducted by Pintrich and his colleagues at the University of Michigan, the MSLQ has become a standard instrument for conducting research on self-regulation and motivation. The generally accepted conclusion is that positive motivational orientations (e.g., intrinsic goal, high task value, high self-efficacy, and low test anxiety) are related to higher levels of self-regulated learning strategies, which in turn are related to better academic performance.[16] Research conducted with the MSLQ can enable instructors to diagnose student characteristics and to develop appropriate instructional strategies to help students improve learning.[17]

Table 2. Sub-Scales of the Motivated Strategies for Learning Questionnaire.

Category	Sub-Category	Sub-Scale	Explanation
Motivational orientations	Value components	1. Intrinsic goal orientation	Perceiving themselves to participate in a task for reasons such as challenge, curiosity, and mastery.
		2. Extrinsic goal orientation	Perceiving themselves to participate in a task for reasons such as grades, rewards, performance, evaluation by others, and competition.
		3. Task value	Learners' evaluation of how interesting, how important, and how useful the task is.
	Expectancy components	4. Control belief	Learners' beliefs that their efforts to learn will result in positive outcomes.
		5. Self-efficacy for learning and performance	A self-appraisal of one's ability to accomplish a task as well as one's confidence in having skills to perform that task.
	Affective components	6. Test anxiety	Cognitive thoughts and emotional feelings toward taking tests.
Learning strategies	Cognitive and metacognitive strategies	7. Rehearsal	Reciting or naming items from a list to be learned.
		8. Elaboration	Building internal connections between items to be learned by paraphrasing, summarizing, creating analogies, and generative

			note-taking.
		9. Organization	Clustering, outlining, and selecting the main idea in reading passages.
		10. Critical thinking	Applying previous knowledge to new situations in order to solve problems, reach decisions, or make critical evaluations with respect to standards of excellence.
		11. Metacognitive self-regulation	The awareness, knowledge, and control of cognition.
	Resource management strategies	12. Time and study environment	Scheduling, planning, and managing one's study time, and setting places to do class work.
		13. Effort regulation	Students' ability to control their effort and attention in the face of distractions and uninteresting tasks.
		14. Peer learning	Dialoguing and collaborating with peers.
		15. Help seeking	Recognizing needs for help, identifying others who can provide help, and asking for help.

Research to Improve Students' Learning of Precalculus

Based on the literature review presented above, it was questioned if using an e-learning program such as ALEKS, compared to using traditional handout-type homework assignments, could be an effective method for helping students learn Precalculus, and whether or not the highly structured e-learning environment in ALEKS would benefit students with different learning styles and motivational characteristics differently. Therefore, a semester-long study was conducted to investigate (1) the effectiveness of using a systematically sequenced and managed, self-paced e-learning program, ALEKS, on academic performance of students with different learning styles (sequential and random), and (2) the relationship among the students' dominant learning styles, their motivational orientations and learning strategies, and their overall academic performance in Precalculus. The research findings would help Precalculus instructors select effective media and methods for handling homework assignments, address individual students' needs based on their learning styles and motivational characteristics, and improve their learning. The research method used in this study is described in the following section.

Method

Research Questions

The study aimed to answer the following two research questions:

1. Is the homework activity administered via ALEKS more effective in helping students with different learning styles (sequential vs. random) learn Precalculus than is the traditional paper-and-pencil handout type homework activity?
2. If any, what relationship exists among Precalculus students' dominant learning styles, their motivational orientations and learning strategies, and overall academic performance in Precalculus?

The first research question was answered by testing the following null hypothesis:

Ho_1: There is no significant difference in students' learning of Precalculus due to the use of different types of homework activity (an e-learning program ALEKS vs. traditional handout assignments) and the students' learning styles (sequential vs. random).

The second research question was answered by examining correlation among multiple variables measured with Gregorc Style Delineator, the MSLQ, and final points students earned from the course.

Subjects

Subjects participated in this study were 138 students enrolled in 4 sections of a Precalculus class offered at a medium-size university in the northwestern region of the U.S. during the spring semester of 2008. It was a 5-credit course; all classes were held for 50 minutes daily, Monday through Friday. The same textbook and course topics were used in all sections. Eighty-three students (61%) were male, and 55 students (39%) were female. The average age of the students was 22 (*SD* = 5.32, *Min.* = 18, and *Max.* = 55).

Research Design

A quasi-experimental factorial research design was used in this study. The two independent variables used for answering the first research question were (1) the type of homework assignments administered in the Precalculus class (e-learning vs. handout), and (2) students' dominant learning styles (sequential vs. random). Two female instructors were assigned to teach the four sections of the class (each instructor taught two sections). To reduce potential instructor bias, one of the two sections taught by the same instructor was randomly assigned to an experimental group and the other section was assigned to a control group (see Table 3). Students in the experimental group used the systematically sequenced and managed, self-paced e-learning program, ALEKS, while students in the control group completed a series of traditional paper-and-pencil, handout-type homework assignments instead. The dependent variable was students' learning of Precalculus.

Table 3. Experimental and Control Groups Taught by Two Instructors.

	Experimental Group using ALEKS homework (*N* =72)	**Control Group** using handout homework (*N* = 66)
Instructor A	Section 004 (*N* = 36)	Section 003 (*N* = 29)

Instructor B	Section 005 (*N* = 36)	Section 006 (*N* = 37)

Research Instruments and Procedure

Students' Pre- and Post-Knowledge in Precalculus: A pre-test was administered at the beginning of the course, and a post-test at the end of the course, and 111 students (80.43%) completed both tests. The pre-test contained 11 questions, and the post-test contained 16 questions, 11 of which were identical to the ones included in the pre-test and the remaining 5 questions of which were also directly related to the topics measured in the pre-test. The scores were recorded in percentage of accuracy.

Students' Learning Styles: To assess students' dominant learning styles, Gregorc Style Delineator was administered during the course, and 104 students (71.33%) completed the instrument.

Students' Motivational Characteristics: Students' motivational orientations and learning strategies were measured with the 15 sub-scales of MSLQ, and 112 students (78.33%) completed the instrument.

Homework Assignments via ALEKS vs. Handouts: Students in the experimental group were given access to ALEKS to complete their homework assignments. Students were assigned to complete 9 intermediate objectives in ALEKS by established deadlines across the semester, and the system kept track of the progress. These were selected to align with the 9 chapter completion deadlines in the accompanying textbook. At the end of the semester, students in the experimental group completed, or mastered 85.0% of the total topics assigned in ALEKS. Students in the control group were provided with handout type homework assignments almost daily. Students were asked to turn in their homework assignments by the first or second following class meeting. The instructors returned the assignments with scores within 2-3 days. Discounting any students that received less than 5% on their total homework grade, students in the control group received an average score of 79.0% on the handout homework assignments. Although the practice questions provided in ALEKS and the questions included in the instructor-developed handout homework assignments were not identical, they were directly related to the topics that students were learning in the course. In both groups, students were aware that the homework assignments were worth 30% of the final grade.

Data Analysis: The data were analyzed with descriptive and inferential statistics using SPSS 17.0 for Windows.[18, 19]

The overall research procedure is illustrated in Figure 4.

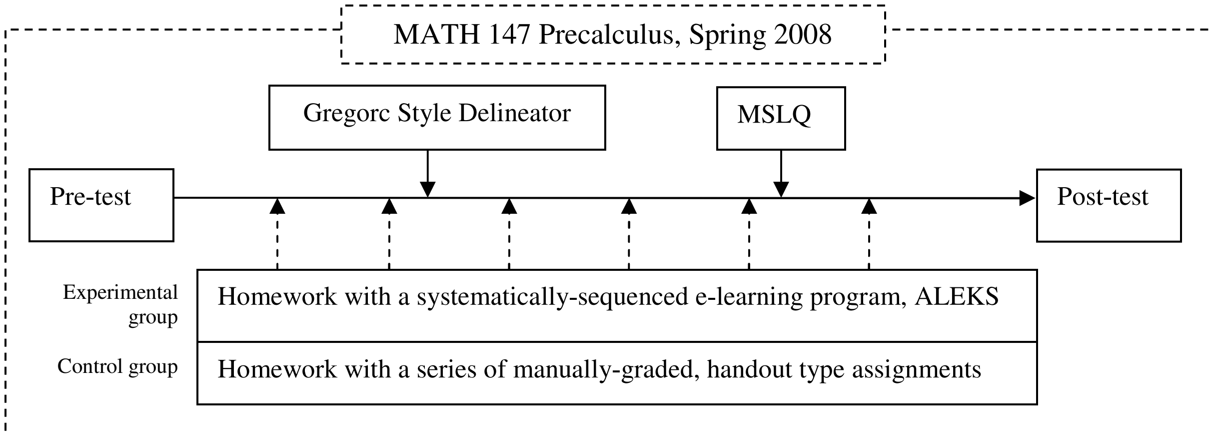

Figure 4. Research procedure.

Results

Effects of Using E-Learning vs. Handouts on Students' Learning with Different Learning Styles

A complete set of pre-test and post-test scores and learning style data were obtained from 98 of the 138 participants (71.0%), and cases with any missing values were excluded in the following data analysis. Most students (93%) demonstrated one of the four styles as their dominant style, and 7 students (7%) showed two or three styles as equally dominant. In those tied cases, computer-generated random numbers were used to select a dominant style.[13] The most frequently identified dominant learning styles among the students were in order, concrete-sequential (N = 42), abstract-random (N = 24), concrete-random (N = 20), and abstract-sequential (N = 12). Among 98 students, 54 of them were sequential-type (CS and AS), and 44 of them were random-type (CR and AR).

The average pre-test scores among the four groups (the experimental-control groups by 2 learning style groups) were not significantly different (see Table 4). Therefore, the post-test scores were compared to test the group differences due to the type of homework activity.

Table 4. Descriptive Statistics of Pre-Test Scores Between Groups.

Homework	**Learning Style**	***N***	***Mean***	***SD***
ALEKS	Sequential	25	9.36	9.738
	Random	19	12.00	8.888
	Total	44	10.50	9.367
Handout	Sequential	29	9.69	8.824
	Random	25	11.32	8.240
	Total	54	10.44	8.518
Total	Sequential	54	9.54	9.171

	Random	44	11.61	8.431
	Total	98	10.47	8.862

The null hypothesis set to answer the first research question was: There is no significant difference in students' learning of Precalculus due to the use of different types of homework activity (an e-learning program ALEKS vs. traditional handout assignments) and the students' learning styles (sequential vs. random).

A 2 x 2 ANOVA was conducted to test the null hypothesis. The average post-test scores of the experimental and control groups were 68.56 (*SD* = 19.87), and 62.00 (*SD* = 20.36), respectively. The average post-test scores of the sequential and random learner groups were 66.45 (*SD* = 20.71) and 63.09 (*SD* = 19.87), respectively. The two-way ANOVA indicated no significant effects due to the types of homework assignments (ALEKS vs. handout homework), $F(1, 94) = 2.05$, $p > .05$, and learning styles (sequential vs. random), $F(1, 94) = .81$, $p > .05$, on students' learning of Precalculus; therefore, the first null hypothesis was retained. The interaction effect on students' learning of Precalculus was not significant either, $F(1, 94) = 1.55$, $p > .05$. However, it is noteworthy that sequential learners who used systematically sequenced and managed ALEKS performed a letter grade higher (*M* = 72.38, *SD* = 18.40) than sequential learners who used handout homework assignments (*M* = 61.34, *SD* = 21.53) and random students who used ALEKS or handout homework assignments (*M* = 63.53, *SD* = 21.10, and *M* = 62.76, *SD* = 19.32, respectively). The group mean differences are presented in Table 5 and illustrated in Figure 5.

Table 5. Descriptive Statistics of Post-Test Scores Between Groups.

Homework	**Learning Style**	***N***	***Mean***	***SD***
ALEKS	Sequential	25	72.38	18.401
	Random	19	63.53	21.107
	Total	44	68.56	19.879
Handout	Sequential	29	61.34	21.534
	Random	25	62.76	19.327
	Total	54	62.00	20.362
Total	Sequential	54	66.45	20.716
	Random	44	63.09	19.878
	Total	98	64.94	20.309

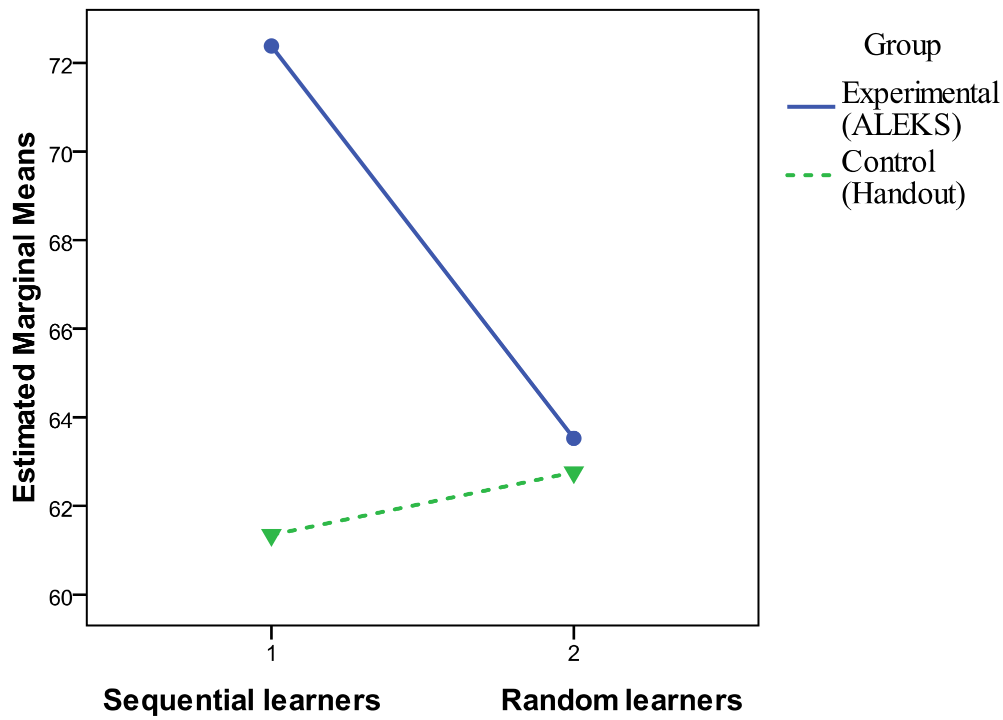

Figure 5. A line graph illustrating the group means of post-test.

Learning Styles, Motivational Characteristics, and Academic Performance in Precalculus

The second research question was: If any, what relationship among Precalculus students' dominant learning styles, their motivational orientations and learning strategies, and overall academic performance in Precalculus exists?

The measure of overall academic performance was the final points earned from the homework activity (30%), 5 quizzes (50%), and the post-test (20%), which determined the final grade of the course. As shown in Table 6, overall, the final points were positively associated with students' intrinsic goal orientation (*rho* = .208), task value (*rho* = .230), control belief (*rho* = .323), self-efficacy levels (*rho* = .655), management of time and study environment (*rho* = .261), and their ability to control effort and attention from distraction (*rho* = .348), and were negatively associated with students' test anxiety (*rho* = -.326) and seeking peer learning (*rho* = -.282).

Table 6. Correlations Among Learning Styles, Motivation, and Academic Performance.

Category	Sub-Scale	CS	AS	CR	AR	Final Points
Motivational	Intrinsic Goal Orientation	.025	.016	.162	-.183	.208*
Orientations	Extrinsic Goal Orientation	.113	.059	-.175	-.038	.135
	Task Value	.148	.232*	.077	-.385**	.230*
	Control Belief	.084	.102	.084	-.187	.323**

	Self-Efficacy	.107	.160	.055	-.253*	.655**
	Test Anxiety	-.104	.034	-.145	.172	-.326**
Learning Strategies	Rehearsal	-.045	-.105	.097	-.008	.096
	Elaboration	.002	-.009	.036	-.032	-.016
	Organization	-.015	.024	-.004	-.023	.064
	Critical Thinking	-.133	.027	.133	-.003	-.021
	Metacongnitive Self-Regulation	.051	-.011	-.043	-.025	.151
	Time and Study Environment	.184	-.021	-.075	-.132	.261*
	Effort Regulation	.200	.090	-.107	-.172	.348**
	Peer Learning	-.008	-.101	.010	.072	-.282**
	Help Seeking	.003	-.075	-.130	.121	-.198
Academic Performance	Final Points	.178	.142	-.062	-.247*	1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Listwise *N* = 96

Only a few small degrees of correlations were found among students' dominant learning styles, their motivational orientations and learning strategies, and final points earned from the course. Task value is about the person's evaluation about how important, how useful, and how interesting the task is. A positive correlation of the task value scores to the abstract-sequential scores (*rho* = .232) confirms that AS-strong students tend to think that it is important and interesting to learn Precalculus that requires abstract-sequential thinking. On the other hand, a notable observation was that students' abstract-random scores were negatively correlated with task value (*rho* = -.385), self-efficacy (*rho* = -.253), and the final points they earned from the course (*rho* = -.247). It can be interpreted in two ways: 1. AR-*strong* students tend to think that learning Precalculus is not interesting or they are not good at learning Precalculus, and they tend to produce lower final points, or 2. AR-*weak* students tend to think that learning Precalculus is interesting or they are good at learning Precalculus, and they tend to produce higher final points. The first interpretation seems to be more plausible with the sample used in this study, because as shown in Figure 6, AR-dominant students performed a letter grade lower than other learning style groups. CS-dominant students scored highest on the final points (*M* = 78.68, *SD* = 12.75) while AR-dominant students scored lowest (*M* = 68.65, *SD* = 17.18). However, the mean differences in the final points shown by their dominant learning styles were not significant at the .05 level. Nonetheless, attention should be paid to this trend associated between AR-dominant students and their tendency toward learning Precalculus.

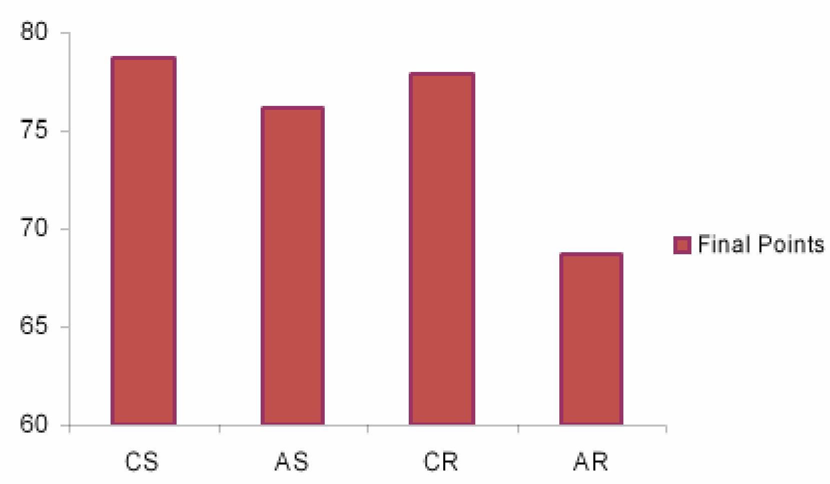

Figure 6. A comparison of average final points by students' dominant learning styles.

Conclusions

Discussion

The purpose of this study was to investigate (1) the effectiveness of using a systematically sequenced and managed, self-paced e-learning program, ALEKS, on academic performance of students with different learning styles in a undergraduate Precalculus class, and (2) the relationship among the students' dominant learning styles, their motivational orientations and learning strategies, and overall academic performance in the Precalculus class. The study revealed that the use of ALEKS and the use of handout homework assignments did not contribute to making statistically significant differences in students' learning of Precalculus. However, a notable trend was observed that sequential students who used ALEKS performed a letter grade higher than sequential learners who used handout homework assignments or random students who used either ALEKS or handout homework assignments.

Interpretations of the above findings are as follows. Learning styles indicate people's abilities in perceiving information and their preferences as to how the information should be arranged.[10] When the learning environment is designed to support their dominant abilities and preferences, learners tend to find it more enjoyable and perhaps perform better as a result. Therefore, it is plausible that ALEKS which is a systematically sequenced and managed learning environment could be more appealing to sequential learners than it was to random learners; and as a consequence, sequential learners who used ALEKS outperformed other groups of learners by one letter grade. However, this study also revealed that random students, especially AR-dominant students, tend not to value the task of learning Precalculus, tend to have less self-efficacy in succeeding in the Precalculus class, and in fact, did not perform as well as other groups of learners. Therefore, another possible interpretation is that it is not just because the ALEKS learning environment supported sequential-type students more and random-type students less, but it could be also because the learning subject matter was more appealing to sequential students and less to random students. This implies that learning is a product of triadic interactions among learners' characteristics, the learning environments, and the learning subjects (see Figure 7).

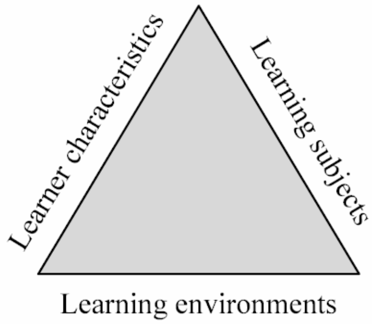

Figure 7. Triadic interactions among learners, learning environment, and learning subject.

This study revealed that the use of ALEKS was not significantly better or worse than the use of traditional handout homework assignments. However, as expected, cost-effectiveness was a benefit of using ALEKS for handling homework assignments. The two instructors indicated that it took about 5 hours per week to manually administer the handout homework assignments, which means that the use of ALEKS freed up 5 hours of their time per week. It implies that an e-learning program such as ALEKS could be substituted for a traditional, time-consuming method for handling homework assignments, allowing instructors to engage in other responsibilities such as curriculum improvement, student advising, and research. However, it should not be over-generalized that e-learning is more effective than instructor-facilitated learning, leading to a conclusion that the entire Precalculus course be taught via self-paced e-learning.

Another interesting observation by the instructors was low class attendance in the two sections of the experimental group that used ALEKS (about 50% attendance), while the students in the control group maintained high class attendance throughout the course (80-90% attendance) although it varied day by day in both cases. It is unknown whether the research results would have been different if the students in the experimental group had also kept as high class attendance levels as the students in the control group.

Limitations of the study

Several limitations exist in this quasi-experimental study. First, it was not feasible to randomly select a sample from the population; therefore, a convenience sample was used. Although two sections taught by the same instructor were randomly assigned to either an experimental group or a control group, potential instructor bias is still a threat to external validity of the study. Also, as a common condition in most educational research settings, the students were asked to participate in the study on a voluntary basis, and complete data obtained from only 71% of the sample were used for data analysis; therefore, the findings of this study should be generalized with some caution. A few threats to internal validity existed, as there were some factors related to the use of ALEKS and handout homework assignments that could not be controlled. For example, by nature, homework assignments, whether they were administered via ALEKS or handouts, were completed in uncontrolled environments; therefore, other confounding factors could interact with the treatment. Although students who used ALEKS might have enjoyed more flexible deadlines to meet, it is also possible that they had less access to the treatment (the use of ALEKS) as it required a computer connected to the Internet, compared to students who used simple handouts.

Recommendations

Based on the findings of this study, the following recommendations are provided to educators who teach Precalculus or related topics:

1. Measure students' learning styles in the beginning of the course. The information would enable the instructors to be aware of their students' potential strengths and weaknesses in performing in classroom and to tailor their instructional strategies toward the individual students with different needs. For example, random students who are studying a subject that demands sequential thinking such as Math may need more attention from the instructors.
2. Have students be aware of their dominant learning styles and motivational characteristics. It can help them self-monitor their learning behaviors and give them opportunities to self-correct ineffective study habits, and develop more effective learning behaviors.
3. Have instructors be aware of their own dominant learning styles and reflect on their preferred approaches for teaching their subjects. Instructors also have their dominant learning styles which are often their preferred teaching styles.[20] For example, CS-dominant instructors may use CS-friendly strategies in their courses. Some common behaviors of CS-dominant people include being adept at following precise step-by-step directions for completing assignments and being good at meeting deadlines. A learning environment with such expectations from the instructor may not appeal to AR students, who like group discussions and collaborative work and tend not to pay attention to meeting deadlines as much.[21]
4. Conduct a more rigorous experimental study in which a sample is randomly drawn from the population. Use a large sample. Measure students' learning styles first to group them into the four learning style groups, and then randomly assign members of each group into an experimental or control group. That way, the findings of the study would provide more statistical power and generalizability.

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