Examining the Self-Regulation Strategies of Students in a Developmental Mathematics Course

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Self-regulated learning (SRL) skills have been linked to academic success, particularly in developmental mathematics courses. This study investigates student SRL strategies in a developmental College Algebra course, taught using Inquiry-Based Learning (IBL) and supplemented with ALEKS. While SRL strategies have been investigated in a variety of contexts, research is lacking in IBL courses with ALEKS support. Data were collected from seventy-four students using open-ended surveys, which were used to answer the research question: What SRL strategies do students use in an IBL with ALEKS course? This was answered in three learning contexts: in-class, ALEKS time, and outside studying. Findings indicate that seeking social assistance and seeking information, especially from ALEKS were the most reported strategies, followed by note-taking and practicing problems. However, very few students reported using SRL strategies related to goal-setting and planning. This suggests that students may need more support in developing SRL strategies, such as through interventions.

Keywords: self-regulated learning, inquiry-based learning, ALEKS, developmental mathematics

Over the last few decades, there have been concerns about the college-readiness of students entering colleges and universities, including discussions on how to prepare students for university level mathematics. One of the principle ways to approach this issue is by including developmental mathematics courses in their catalog, which often have large enrollment rates (Chen, 2016). However, there is often a high withdrawal rate for the students in developmental mathematics courses (Adelman, 2004).

One vital component of student success in mathematics classes is students' ability to self-regulate their learning. Self-regulated learning (SRL) is the ability of a student to take an active part in their learning process, by setting goals and motivating themselves, using different strategies to complete their learning task, and reflecting on their learning and strategy usage (Zimmerman, 2002). Students with more SRL strategies have often improved in their mathematics scores (Kramarski & Gutman, 2006; Mevarech & Fridkin, 2006; Throndsen, 2011), while students who do not possess these SRL strategies often struggle more in mathematics courses (Bol & Garner, 2011, Isaacson & Fujita, 2006; Ley & Young, 1998; Zimmerman, 2002).

SRL interventions have yielded positive results, helping both improve students' SRL skills, as well as their mathematics scores (Bol et al., 2016). Another possible approach to improving students' SRL skills is by creating more active learning-based classes (McDonough & Sullivan 2008; Zimmerman 2002). For example, classes using a problem-based learning model showed increases in SRL skills (Blumberg 2000; Sungur & Tekkaya, 2006). This also connects with the university efforts to create more active learning-based mathematics courses, as the benefits of active learning have been well documented (e.g. Freeman et al., 2014).

One specific type of active learning model is known as Inquiry-based learning (IBL), where students are given investigative tasks that allow them to be engaged in the creation of important mathematics (Laursen & Rasmussen, 2019). Generally, in IBL classes students are practicing mathematics as a mathematician would. For example, creating and testing conjectures, making generalizations, providing justifications, and reflecting on their conclusions (Mesa et al., 2020). IBL generally involves student collaboration, where students work together to build their

knowledge, while the instructor facilitates the learning rather than being the sole source of knowledge. IBL has generally seen positive effects on academic achievement in mathematics classrooms, as well as reducing learning gaps for underrepresented students (e.g. Kogan & Laursen, 2014; Laursen et al., 2014).

Another common change universities are making is by implementing technology like intelligent tutoring software. A specific type of software that does this is Assessment and Learning in Knowledge Spaces (ALEKS), which has been used more in the last decade in mathematics courses (Cosyn et al., 2021). ALEKS provides examples and tutorials to students while assessing their understanding. Research on ALEKS has been mixed, with some research finding ALEKS was at least as good as a traditional lecture course (Sun et al., 2021) but some research finding ALEKS did not affect the passing rates (Childers & Lu, 2017). However, in mathematics classes, ALEKS seemed to have a more positive effect when used as a supplement to an active-learning style classroom (Boyce & O'Halloran 2020; Sun et al., 2021).

Theoretical Perspective

One prominent model of SRL is Zimmerman's (2002) model, which has three phases: the forethought phase, the performance phase, and the self-reflection phase (Zimmerman, 2002). The forethought phase includes analyzing the task at hand and motivating oneself to perform the task. Analyzing the task includes setting goals and determining specific strategies to accomplish these goals. Motivation includes self-efficacy, which is a student's belief in how well they can complete a task. Self-efficacy is often affected by the student's perceived skill level, outside factors like feedback from instructors or peers, and observing peers performing the task (Bandura, 1977). Motivation also includes intrinsic motivation, or how much the student is interested in the task and what they hope to achieve by completing the task.

The performance phase occurs during the completion of the task. This phase involves how a student completes a task, such as how they focus, the time they spend on the task, and the different strategies they use. The performance phase includes self-observation, where the student monitors their progress, tries different strategies, and changes or adopts them depending on their perceived effectiveness. Examples of strategies may be working with peers or taking breaks.

Once the task is complete, the self-reflection phase begins. In this phase, the student evaluates themselves, for example by comparing their task completion to the task standards. This also includes a self-reaction, where the student may feel satisfied with the task and adapt the new learning strategies or become defensive and not change their strategies. This then leads into and affects the forethought phase of the next task, completing the cycle.

This study sought to explore the SRL strategies of students in developmental mathematics courses. My research questions are: What self-regulated learning strategies do students use in an IBL with ALEKS course?. Specifically, (1): What self-regulated learning strategies do students use during the IBL class-time? (2) What self-regulated learning strategies do students use during the ALEKS homework time? (3) What self-regulated learning strategies do students use during outside-class time, not including homework?

Methods

The course studied is a developmental but credit-bearing mathematics course, College Algebra with Review, taught at a mid-sized, PhD granting university in the Midwest. This course has the same content as the regular College Algebra course but has more credit hours and therefore more in-class time. This extra in-class time allows students to work through the same content at a slower pace and alleviates some concerns about active learning requiring more class

time. The content of this course is basic algebra, coordinate geometry, and functions. The course description on the syllabus includes "[the] course is taught using Inquiry-Based Learning with a focus on collaboration". Instructors of this course are given advice by the course coordinator and materials to use during the semester, but the day-to-day activities and teaching methods are up to the instructor, allowing variability in the IBL with ALEKS implementation by class section.

Five instructors and their students participated; one instructor taught two sections and the others each taught one section. Students from all sections were chosen using self-selection sampling, where the participants could participate in a Qualtrics survey. This survey was administered after the first exam. The number of students participating in each section were: Section 1 (both sections from one instructor): 23 (28%); Section 2: 16 (41%); Section 3: 9 (23%); Section 4: 12 (30%); and Section 5: 14 (35%), for a total of 74 participants.

Data was collected using student questionnaires containing open-ended questions to provide in-depth understanding of the students' SRL strategies. The questionnaire was designed to avoid providing examples of strategies to the students. The questionnaire was designed around Zimmerman & Pons' (1986) structured interview, which was developed to assess students' use of SRL strategies, and included questions about the following categories of learning strategies: self-evaluation, organizing, goal-setting and planning, seeking information, keeping records and monitoring, environmental structuring, self-consequences, rehearsing and memorizing, seeking social assistance, and reviewing records. For this project, I am interested in the dichotomy of the class setup, where students learn with IBL in the class but have ALEKS software guide them for homework. Therefore, I modified the categories to include both in-class and ALEKS contexts to illustrate and shed light on these contextual differences.

I initially coded the responses from questions 1-3 using the modified Zimmerman & Pons' (1986) codebook. These questions were phrased by giving a context and asking students to write out their methods. For example, question 1 was "[The math course] has in-class sessions that may involve listening to the instructor, working on problems individually, collaborating in groups, or having whole-class discussions. What particular methods, if any, do you use to help you learn and understand the mathematics content during class?" Each participant response could receive multiple codes, including the same code multiple times, in the case participants described two different strategies that fit with the same code. As the responses were coded, the categories were split into a few different subcategories or codes, based on the student responses, and some categories were added. After completing the codebook for questions 1-3, questions 4 and 5 were then coded with the same codebook. Questions 4 and 5 asked more broadly about their study habits. For example, "Think about your general process of preparing for and studying for [this math course]. How do you prepare for and study for this class?". Therefore, the responses were generally longer and more complex but still ranged between one and five sentences. When coding questions 4 and 5, two extra categories were added.

Results

What SRL Strategies do Students use During the IBL Class Time?

Table 1 lists the frequencies of codes in relation to each question. Seeking social assistance occurred most frequently with 58 participants using at least one of the strategies in this category. The prevalence of the strategies focused on social assistance is consistent with the class structure, which emphasized collaborative learning. 40 participants described learning with their peers, which were coded as Peer-Learning or Peer-Seeking. Peer-Learning was used when participants described working with groups generally and often had statements concerning

collaborative learning. For example, one participant described this as "finding an answer and comparing it with another person, if we get different answers, then I solve using their method and see if it would apply better." The code Peer-Seeking was used on statements describing asking group members for help if they were struggling, such as "ask my group if I don't understand". With this mixture of codes, the participants appeared to be using the group work sessions both to get help from their peers, as well as for collaborating with others, suggesting students may use group work differently. In addition, 18 participants were coded with Instructor-Seeking and Tutoring-Seeking, with 16 and 2 participants respectively. This is consistent with the class style, as the instructor walked around during group work, providing help for groups.

Table 1. Codes and Frequencies

Category	Code	Q1	Q2	Q3	Q4-5	Total
Seeking social assistance	Peer-Learning	29	1	9	6	36
	Peer-Seeking	11	6	2	15	23
	Instructor-Seeking	16	0	3	20	29
	Tutoring-Seeking	2	3	2	7	11
Seeking information	ALEKS-Seeking	8	2	5	16	29
	Explanations-Seeking	0	39	0	10	41
	Notes-Seeking	6	11	0	27	32
	Video-Seeking	2	6	5	13	22
	Internet-Seeking	2	9	4	8	19
Keeping records and monitoring in class	Taking-Notes	19	0	0	5	22
	ALEKS-Notes	0	16	0	5	17
	Problem-Notes	0	5	0	1	6
Organizing	Summarizing	2	0	0	1	2
Self-Evaluation	Self-Evaluation	3	8	5	3	15
Rehearsing and memorizing	Rehearsing-Flashcards	1	0	1	0	2
	Rehearsing-Formulas	1	1	1	5	6
	Rehearsing-Problems	13	3	7	0	22
	Rehearsing-Steps	0	1	0	0	1
	Rehearsing-Review	2	0	8	10	14
Environmental structuring	Music-Structuring	0	1	0	0	1
	Library-Structuring	0	2	1	2	5
Reviewing records	Reviewing-Quizzes	0	0	4	6	9
	Reviewing-Notes	0	0	10	0	10
Goal-Setting/Planning	Goal-Setting	0	0	0	7	7
Effort Regulation	Effort-Regulation	0	2	0	8	10
	Paying-Attention	0	0	0	2	2

The next most frequent categories were Keeping records and monitoring in class (19), Seeking information (17), and Rehearsing and memorizing (17). The only code that was utilized in Question 1 was Taking-Notes. The category Seeking information had 17 instances, spread across four codes: ALEKS-Seeking (8), Notes-Seeking (5), Video-Seeking (2), and Internet-

Seeking (2), while Explanations-Seeking had no instances. However, Question 1 asked about in-class strategies, so it is possible that the students interpreted the question as asking about the course generally, rather than only their in-class activity. Finally, six participants were coded with Note-Seeking, where they described using previously made notes to help with their understanding, such as "[Using] notes from previous work, either in class notes or ALEKS".

For the Rehearsing and memorizing (17) category, four different codes were used: Rehearsing-Problems (13), Rehearsing-Review (2), Rehearsing-Flashcards (1), and Rehearsing-Formulas (1), with no participant being coded with Rehearsing-Steps. 17 participants described using practice problems to help with their understanding, such as "writing the same question repetitively and troubleshooting until I find a method that applies to each question.". This was the most common code, with only a few other participants using the other strategies.

The categories Summarizing and Self-Evaluation were coded to two and three participants respectively. Summarizing most likely referred to outside of class activities, such as "write examples/notes to revise later if I need to remember how to do something". Self-evaluation was only described twice, such as "Finding an answer and comparing it with another person, if we get different answers, then I solve using their method and see if it would apply better.". The four categories Environmental structuring, Reviewing records, Goal-Setting and Planning, and Effort Regulation were not coded to any participants.

What SRL Strategies do Students use During the ALEKS Work Time?

The category Seeking information was the most frequently used category of codes, with a 67 participants. The most common code was Explanation-Seeking, with 39 participants. This referred to the ALEKS showing explanations. Notes-Seeking (11), Internet-Seeking (9), and Video-Seeking (6) showed that participants were also referring back to their classroom notes or worksheets to help study and using the internet and video websites as well. While ALEKS helps explain topics and has videos, some participants were still using outside resources. Finally, ALEKS-Seeking was used twice, where participants used ALEKS more often than required.

The next most frequent category is Keeping records and monitoring in class, with 21 participants. With 16 participants making statements about taking notes while working in ALEKS, note-taking appears to have a similar importance to students as note taking in class, which has 19 such codes. This strategy also shows more involvement with the software, as those students are not only trying to solve the problems and read the explanations but trying to record important information. The second code is Problem-Notes, as six participants considered writing down the problem in their notebook to solve, a strategy to help them learn.

The category Seeking social assistance was coded for 10 participants. Seven participants were coded with Peer-Seeking or Peer-Learning, implying that some students work together on their ALEKS work. Three participants were also coded with Tutoring-Seeking. Eight participants also used Self-Evaluation strategies during their ALEKS time. For example, one participant described evaluating their work as: "[I] try solving an example problem on my own before looking at the answer". This strategy shows more involvement with self-guided learning, where the student is working through the problem themselves, and evaluating the work afterwards.

Rehearsing and memorizing had five participants coded, with three participants describing using more practice problems in ALEKS to study. One participant described writing out the steps to help, while another participant described writing down equations. This may imply students are focusing on working through the problems in ALEKS as strategies.

Finally, three and two participants respectively were coded in the category Environmental structuring and Effort Regulation. These focused on working in the library. The two participants

coded in Effort-Regulation described taking regular breaks from ALEKS. No participant was coded with the categories Summarizing, Reviewing Records, or Goal-setting and planning. While Summarizing and Reviewing Records may not be as relevant to ALEKS work, it was surprising that there were no mentions of Goal-seeking and planning. With the course requirements of three hours of ALEKS a week and a certain number of modules completed, setting goals seems like it would be a common strategy to be utilized.

What SRL Strategies do Students use During Outside-class, Non-ALEKS Time?

The category Rehearsing and memorizing contained seventeen participants, with the majority of codes being Rehearsing-Problems and Rehearsing-Review. The students described practicing problems to help them review. For exam 1, which was administered prior to this survey, the students were all given study guides covering review problems. Eight participants specifically described using these to help review, such as "I do the optional review work and check my answers with the key". One participant also described reviewing using flash cards, and another by writing down all the formulas multiple times.

Sixteen participants were coded with Seeking social assistance, with 11 students seeking peer support specifically. These included statements about study groups, such as "helping and explaining to a friend". The category Seeking information had fourteen participants, with relatively equal amounts of codes for using ALEKS, the internet, and online videos to review.

Fourteen students were categorized in Reviewing records. Ten students were coded with Reviewing-Notes, using their past lecture or ALEKS notes for better review. For example, one participant described using their notes by: "looking through the notes taken during class and retrying problems that I got wrong and seeing if I could get them correct", where their in-class notes were helpful, using the important problems they recorded. In addition, four students were coded with Reviewing-Quizzes, where they used their past quizzes and feedback to review.

Finally, five students were classified using the code Self-Evaluation. For example, this participant describes working through problems they struggled with, then assessing their work: "[I] write a question on a worksheet I struggled with and try to answer it without looking back at the worksheet". One student was also coded Environmental structuring, having studied in the library. Summarizing, Goal-setting, and Effort-Regulation were not described in question 3.

What SRL Strategies do Students use in an IBL With ALEKS Course?

The purpose of questions 4 and 5 were to help students provide strategies regarding goal-setting and planning, as well as giving them a chance to list more learning strategies they may have forgotten. Seven participants described goal-setting across questions 4 and 5, such as: "I work with my group outside of class on the assignment given to us for the next class at the library". Here, they had a goal of preparing for class beforehand, and planned study sessions with their group members to help be prepared when class starts. The category Effort-Regulation was described by 10 participants. For example: "I get up frequently and walk away from my computer, either to go outside or grab food to give myself a break". Two participants were also coded with the code Paying-Attention. For example, one participant wrote "I prepare [for class] by getting as much sleep as I can", which may help the student stay focused during class.

The category Seeking information saw higher rates of ALEKS-Seeking, Notes-Seeking, and Video-Seeking in questions 4 and 5, compared to questions 1-3. This implies that there are still a variety of sources students look to when the material is difficult, with their notes being a more common source, but also ALEKS and videos online. The most frequent category of SRL strategies is Seeking information. Using ALEKS to help with studying contained the most

substantial codes. Video-Seeking and Internet-Seeking had frequencies of 22 and 19 respectively. A similar number of participants (33) described using the notes they took, either in-class or during ALEKS, to help them study. Seeking social assistance was the next most common category, focusing on their peers, with 23 Peer-Seeking codes and 36 Peer-Learning codes. 29 and 11 participants were coded with Instructor-Seeking and Tutoring-Seeking respectively; thus, some students did seek out their instructors if they needed additional support. However, most of the codes involving asking the instructor for help were in Question 1, so it is possible the Instructor-Seeking occurred mostly during class.

Keeping records and monitoring in class, as well as Rehearsing and memorizing were the next most frequent categories, which was also described in previous questions. Rehearsing and memorizing focused mostly on using and practicing with practice problems (22), which is consistent with mathematics courses. 14 participants also described using instructor created exam review sheets. Although other strategies for memorization were listed (such as using notecards), they were only described by a few participants. Self-Evaluation was mentioned by only 15 participants. Most of these instances revolved around using ALEKS. Reviewing quizzes (9), Effort-regulation (12), Goal-setting (7), Environmental structuring (6), and Summarizing (2) had less frequencies compared to the other codes and categories. It was expected that Goal-setting, Environmental structuring, and Effort-regulation would have more instances, as the course had relatively strict requirements with ALEKS. However, it is possible that the participants did not consider these strategies or thought they did not apply based on the questions in the survey.

Discussion

Overall, the SRL strategies used by the participants matched the categories originally given by Zimmerman and Pons (1986). The most common SRL strategies used were Seeking social assistance and Seeking information, focusing on ALEKS and online sources. The strategies of taking and reviewing notes from lecture and ALEKS were also commonly used strategies, as well as practicing problems to help with memorization. However, other memorization strategies, as well as the SRL strategies of Self-Evaluation, Organizing, Environmental structuring, Goal-Setting, and Effort-Regulation were not utilized by many participants. Instead, participants seemed to be focusing on strategies to learn the in-class material and using ALEKS for practice. This also connects to the issue that students did not describe many goal-setting strategies, even when prompted, which is an integral part of the SRL cycle. This may suggest that the course structure is beneficial for the Performance Phase of Zimmerman's (2002) cycle, but students are struggling with the Forethought Phase. However, this might be addressed by incorporating literature on goal setting, such as weekly goal-setting journals (Bol et al., 2016).

One limitation is that the survey was administered close to the start of the semester. This is the time students are still getting used to the course, have just completed their first exam. Therefore, after getting their exam scores, students may reflect on their study strategies and adapt as the semester goes on. As the in-term exams are the largest assessments students receive (outside of the final exam), students may not have been focusing much on the Self-Reflection phase. In this case, all of the students' feedback came from ALEKS and smaller weekly quizzes, so they may not have been evaluating their general study habits, and instead focused on smaller issues they were having with specific content. This could also explain some of the issues with goal setting described above; that is, it is possible students may have started adding more goals after evaluating themselves after the exam. It would be beneficial to do more research specifically on goal-setting in this style class, or to see if any of these SRL strategies change throughout the semester.

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