Exploring Relationships Between First-Semester Calculus Students' Self-Regulation Strategies and Their Mathematics Identity and Mathematics Self-Efficacy

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This mixed-methods study examines the self-regulation strategies that first-semester undergraduates use in a first-semester calculus course through quantitative analysis of student survey responses and qualitative analysis of student interviews. The relationship between these self-regulation strategies and both mathematics identity and mathematics self-efficacy was found to be positively correlated. The strategies of metacognitive self-regulation, effort regulation, and time and study environment were found to be the most commonly used strategies by academically successful students based on a large-scale survey given to 188 first-semester calculus students as well as from interviews that occurred throughout the Fall 2021 semester.

Keywords: Calculus, Undergraduate Mathematics, Self-Regulation, Self-Efficacy, Mathematics Identity

The transition from high school mathematics to undergraduate mathematics presents challenges for many students in the United States (Clark, 2005; Gueudet, 2008, Ulriksen et al., 2017). These challenges include difficulty with foundational mathematics content, lack of self-regulation strategies, low degrees of self-efficacy, social challenges of being in a new environment, and institutional challenges of interacting with a new institutional system (Hernandez-Martinez et al., 2011 and Seymour & Hunter, 2019). High failure rates in college calculus as reported by Bressoud et al. (2015), Rasmussen et al. (2019), and Seymour and Hunter (2019) highlight the need for academic intervention for incoming college students. This intervention includes not only attending to the mathematics content understanding needed for success in first-semester college calculus, but also developing effective study strategies and self-regulation strategies employed by successful calculus students. This case study presents findings from a larger study that explores the self-regulation strategies of first-semester calculus students and how those strategies relate to their mathematics self-efficacy and mathematics identity.

To adjust to these challenges, students employ self-regulation strategies as researched by Zimmerman and Pons (1986) in a high school setting and by Wolters (1998) and Johns (2020) at the undergraduate level. In a mathematics setting, self-regulation strategies can be thought of as actions used to overcome some obstacle when working on tasks associated with a mathematics classroom. This can be in relation to specific mathematics problems and strategies used when experiencing some difficulty, or more general strategies or practices regarding tests and studying. In this report findings related to the following research questions are presented and discussed: "In what ways do students adapt self-regulation strategies from high school mathematics to college-level mathematics?" and "How does a student's mathematics identity and/or mathematics self-efficacy relate to their implementation of self-regulation strategies?"

Conceptual Framework

Zimmerman and Pons (1986) and Wolters (1998) identified categories of self-regulation strategy usage in high school students and undergraduate students respectively. The categories developed by these researchers include seeking information, keeping records and monitoring, organizing and transforming information, seeking assistance, self-evaluating, setting goals,

providing rewards, changing environmental conditions, and identifying internal motivational factors such as interest, self-efficacy, emotion, attention, and willpower. Zimmerman and Pons argue that as students use the strategies and reflect on how they use the strategies, that their overall strategy usage will improve.

Johns (2020) examined the self-regulation strategies used by students enrolled in a first-semester calculus course, especially as it correlated with academic performance. In Johns' study she examined student responses to the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1991) which gave a quantifiable measure of what strategies students used in a particular course setting. This data was then correlated with overall course grades for her 424 participants, and it was shown that there was a positive correlation between student course grades and the number of self-regulation strategies used.

Researchers find that positive mathematics identity and high degrees of mathematics self-efficacy contribute to students' persistence in a mathematics-based major and higher academic achievement. For example, the ways in which students view themselves as mathematics learners can be a motivating force for whether they will further their mathematics career (Cribbs et al., 2015; Gutiérrez, 2013; Ulriksen et al., 2017). Also, high measures of self-efficacy have been correlated with higher academic achievement, more frequent completion of academic goals, and academic persistence (Bandura, 1997; Hackett & Betz, 1989; Tinto, 2017; Usher & Pajares, 2009). Hernández-Martínez et al. (2011) argue that during times of transition and difficulty there is a restructuring of mathematics identity that can occur for students, such as in the transition from high school to college mathematics.

How self-regulation strategies are used and developed by undergraduates in mathematics courses has not been widely studied while attending to transition to college mathematics and connections between self-regulation strategy usage, mathematics identity, and mathematics self-efficacy. Gueudet (2008) outlined several of the challenges that arise during the transition to tertiary school, especially related to individual, social, and institutional phenomena. For the individual phenomena, Gueudet describes that undergraduates beginning the transition often lack flexibility of switching between different thinking modes, such as practical and theoretical thinking. Sonnert et al. (2020) found that high school preparation was a significant factor on retention and performance for first-year students, but as the distance from high school grows the influences lessens. Though for those first-year students it was preparation in mathematics, and to a lesser extent attitudes about mathematics, that had the largest impact on performance in a calculus class. This is attributed to the highly cumulative nature of mathematics. Self-regulation strategies play an important role in helping students to adapt to and overcome these transitional challenges.

Methodology

This report focuses on two individual student interviews for each of the six first-semester undergraduate students participants enrolled in a first-semester calculus course and participant responses to a large-scale survey. Interviews occurred throughout the Fall 2021 15-week semester. The study occurred at a large, urban research university in the Southwestern United States. All first-semester calculus courses meet two (for 80-minute lecture periods) or three (for 50-minute lecture periods) times a week for lecture. Two additional weekly 50-minute meetings engage students in a collaborative lab activity facilitated by the instructor and graduate teaching assistant (GTA) for one class meeting and traditional recitation activities facilitated by the GTA during the other meeting. Each of the courses have departmentally coordinated exams written by the course instructors, these exams are typically offered the fourth full week of the semester, the

ninth full week of the semester, and the final exam during the last week of the semester. Of the five interviews, the two individual interviews occurred within a week of the first midterm and within a week of the final exam. These interviews lasted 20-30 minutes and focused on students' mathematics background, self-efficacy, and identity as well as differences between their experiences in high school and college mathematics. The other three interviews were task-based group interviews, lasting 50 minutes to an hour, occurring a week before each midterm and the final exam.

The initial surveys were sent to thirteen first-semester calculus sections which included approximately 800 students. Of those invited, 188 students completed the initial survey which included background information, the MSLQ (Pintrich et al. 1991), a survey to measure mathematical identity (Kaspersen, 2016), select questions from the Factors Influencing College Success in Mathematics (Sonnert et al., 2020), and a survey to measure the sources of self-efficacy (Usher & Pajares, 2009). Scores for each category were calculated using the scoring rubric provided with the MSLQ. Once self-efficacy, mathematics identity, and self-regulation strategy usage had all been scored, a scatterplot was created. Each score for the MSLQ strategies could range from 0 to 7, where 0 indicated that a participant never used the strategy and higher scores indicated a stronger, more frequent, use of the strategy. From the MSLQ the authors state that a score above 3 indicates an adequate use of the strategy. A weighted average was calculated from the MSLQ scores and related to both the self-efficacy scores and mathematics identity scores on a graph along with the correlation coefficients. For self-efficacy, a low score would indicate that a student is not confident in their ability to complete mathematics tasks, while a high score indicates a strong confidence in that ability. The mathematics identity score relates to how strongly a student perceives themselves in relation to mathematics. A low score would indicate that the student does not see themselves as being particularly mathematically minded, while a high identity would indicate that students see themselves as being highly mathematically minded.

To obtain an interview pool of first-time first-semester freshmen with differing measures of self-efficacy, mathematics identity, and self-regulation strategy usage on the initial survey, 38 of the students were invited to participate in a sequence of five interviews. Of these, seven accepted and began the interview sequence, with one student dropping out after the third interview. Table 1 provides information of the interview participants, including their pseudonym, major, and the highest level of mathematics course they took in high school.

Table 1: Interview Participant Information

Participant	Major	Highest Mathematics Course Taken in Secondary school
Aria	Civil Engineering	AP Calculus AB
Cyndy	Biology	Precalculus
Frank	Computer Engineering	AP Calculus AB
Jane	Architectural Engineering	Calculus
Jay	Computer Science	Trigonometry
Sunny	Computer Science	AP Calculus BC

A case study methodology was chosen to explore individual experiences of undergraduates' transitions to college mathematics and their uses of self-regulation strategies. A mix of qualitative data from the interviews and quantitative data from the initial surveys helped formulate our depiction of the students' transition. Content analysis (Stemler, 2000) methods

were used to analyze interviews. For each interview an audiovisual recording was made and transcribed verbatim. Participants were given pseudonyms. To code the data, the first author used codes derived from synthesized categorizations by Zimmerman and Pons (1986) and Wolters (1998) and developed codes related to statements related to mathematics identity, self-efficacy, and differences between high school and college mathematics experiences. To ensure inter-rater reliability, the second author coded a subset of the interviews for comparison. Most codes were consistent across coding instances, and any differences were resolved.

Findings

Through the analysis of the initial survey and interviews, findings related to the relationship of self-regulation strategies to students' mathematics identity and mathematics self-efficacy were determined. First, the results of the initial survey and the quantitative data collected will be presented. Secondly, the results of the individual interviews will be presented as they inform the research questions.

From the 188 initial survey participant responses, a positive correlation between self-regulation strategy usage and mathematics self-efficacy and identity can be shown. In the following two figures (Figure 1 and Figure 2) we see the general trend of the data where self-regulation strategy usage, mathematics identity, and mathematics self-efficacy scores were determined as described in the previous section.

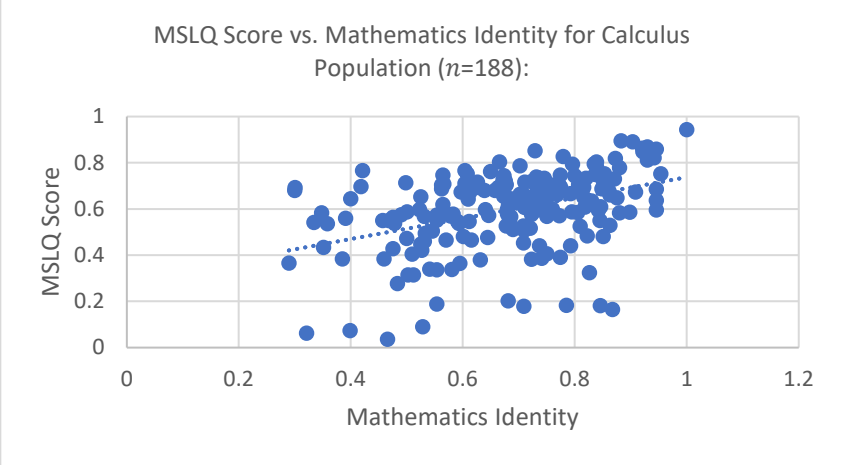

Figure 1. Population of Calculus participants' ($n = 188$) score obtained from Motivated Strategies for Learning Questionnaire versus Mathematics Identity score. Pearson's $r = 0.4101$

Figure 1 shows that as mathematics identity scores increase student use of self-regulation strategies tends to increase also. There is a moderately positive correlation between participants use of self-regulation strategies and their mathematics identity scores.

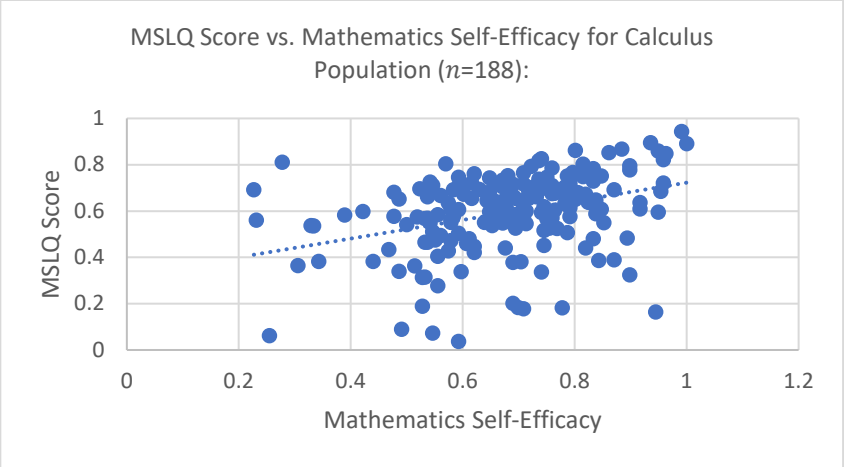

Figure 2: Population of Calculus participants' ($n = 188$) score obtained from Motivated Strategies for Learning Questionnaire versus Mathematics Self-Efficacy score. Pearson's $r = 0.3589$

As in Figure 1, Figure 2 shows a moderately positive correlation between the use of self-regulation strategies as determined by the MSLQ score and participants mathematics self-efficacy. Aside from the correlation data, data about individual participants' self-regulation strategies was found using the MSLQ. Comparing the scores from the MSLQ with participants' self-reported expected course grades it was found that three major strategies emerged as being frequently used by successful undergraduates in a first-semester calculus course. These three strategies were metacognitive self-regulation, effort regulation, and time and study environment. These strategies were also present with the academically successful interview participants as will be described later in this paper.

Along with the initial questionnaire data, data about participants' self-regulation strategy usage as it relates to mathematics identity and self-efficacy was examined through the individual interviews that occurred at the beginning and end of the semester. Within the interviews participants spoke about their general study habits in high school and how they studied for each midterm in their college calculus course. They also reported on their confidence as a mathematics student and how they saw themselves as mathematics learners. Based on their responses to the initial survey, interview participants had self-efficacy and identity scores that ranged from medium to high, but no participants with low scores agreed to be a part of the interviews. The examination of those participants with higher scores of mathematics self-efficacy and mathematics identity was used to identify what strategies students tended to employ. This analysis provides a preliminary framework of self-regulation strategies that could benefit students in their transition to undergraduate mathematics courses. From the initial questionnaire, while the three strategies of metacognitive self-regulation, effort regulation, and time and study environment were present in the interview participant responses, examining the successful interview participants' strategies also revealed they had a high frequency of organization and elaboration of course content.

From both interviews key elements emerged regarding how participants adjusted their study habits for exams from high school mathematics to college mathematics can be shown. Moving to a college setting, participants discussed how they expected to study on the calculus midterms, before having taken any mathematics midterms, and then during the final interview they discussed how they studied for the first and second midterms. The strategy most used in a high school course by these six students involved self-evaluating understanding by using test reviews

or memorization tools. The next most used strategy was to seek peer assistance. Several of the participants reported that they did not expect to change their study habits significantly, but for those that did, the participants reported that they would seek external resources to further their understanding of the course content. Participants reported using more self-regulation strategies than they at first anticipated. While seeking external resources was one of the most reported additions to studying for the college mathematics midterms, most of the participants also reported adjusting their routine of studying, indicating that they spent more time studying for college exams than in high school. A couple participants, Jane and Jay, also reported adding other strategies including setting performance goals such as striving to earn a B on a particular midterm because that is what is needed to pass the course. Participants reported that this increase in strategy usage was heavily influenced by the first midterm grade and perceived difficulty of future exams; the first midterm either being lower-than-expected in Cyndy, Jane, and Jay's cases, or in the cases of Aria, Frank, and Sunny having a high midterm and resolving to keep the grade high which required additional studying.

Along with changing their strategy usage to adjust to the difficulty of the course exams, participants also discussed whether their perceptions of their mathematics identity and mathematics self-efficacy had changed. Based on the initial survey, Jane and Sunny had the highest scores of self-efficacy and mathematics identity, with all the other participants having a score indicating a medium degree of self-efficacy and mathematics identity. Cyndy and Jay reported that their confidence in their ability to work mathematics tasks was lower than when starting the course, although Jay did add that by becoming less confident it made her realize that she needed to spend more time and effort studying and preparing for exams, especially through self-evaluation of her understanding. Aria, Frank, Jane, and Sunny each reported raising their confidence levels throughout the semester, citing that their understanding of the material and the requirement of needing to know the material at a deeper level than high school improved their confidence. Jane did add that although her grade lowered, like Jay, this change in performance helped her reflect on how to better her study habits and require her to increase the effort she put into her mathematics course. Only two participants reported any change to their mathematics identity during their first semester of college. Jay reported that she did consider herself good at mathematics during the first interview, but during the final interview no longer held that belief of herself. Sunny on the other hand increased her perception of herself as a mathematics student. In general, data from the interviews and initial surveys show that these interview participants had higher rates of self-regulation strategy usage as their mathematics identity and mathematics self-efficacy increased, although in some cases like Jay, it was through the reflection that her self-efficacy had decreased that motivated her to better her study habits. Additionally, while the overall use of strategies tended to increase, in the case of Jane it was reported that she did not use certain beneficial strategies, such as seeking assistance from peers or instructors, because of her high degree of mathematics identity which led her to believe that she needed to be able to solve the problems independently to be good at mathematics.

Discussion and Conclusion

Participants in the study adapted their self-regulation strategies to the college setting by changing their study habits in response to exam performance and the increased difficulty of the course. This adjustment tended to involve some reflection about their study habits, an increase to time spent studying, or improved effort while studying which could take the form of attending to test reviews more frequently or seeking assistance from peers or instructors. Participants reported expecting a need to increase or change their high school study habits, but not to the degree that

might be necessary. This finding aligns with Collier and Morgan's (2008) report that indicated undergraduate students did not expect to spend as much time per week studying in general undergraduate courses as what was recommended by the faculty that taught those courses. Almost all participants added or changed some aspect of their self-regulation strategy of setting a routine by increasing the time spent studying to adjust to the difficulty of the course, and specifically the difficulty of early exams. Participants were inclined to continue using strategies that worked for them in high school, but after recognizing the higher cognitive demand of their college course and the difficulty of their exams, participants adapted their study habits.

To inform the relationship between self-regulation strategy usage and mathematics identity and self-efficacy, we see a positive correlation between these factors as measured by the MSLQ, the mathematics identity survey by Kaspersen (2016), and the self-efficacy survey by Usher and Pajares (2009). Within the interviews we also saw that participants' discussions of their mathematics identity and self-efficacy affected their self-regulation strategies. As some participants, when their self-efficacy or identity was challenged by the difficulty of the course, were motivated to increase their use of self-regulation strategies to better their academic standing in the course. This positive correlation between self-regulation strategies versus mathematics identity and mathematics self-efficacy supports Hackett and Bets' (1989) call for promoting positive development of students' mathematics identity and self-efficacy at a young age. This also relates to Tinto's (2017) recommendation that development of self-efficacy can be accomplished through careful monitoring of first-year college students to provide social and academic support when facing difficulties.

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