Self-Regulation in Calculus I

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Improving STEM retention is a major focus of universities and studies have shown calculus to be a barrier for STEM intending students. Prior to this study, local data indicated students did not pursue STEM fields because they were not passing calculus. In this work, I report on the results of a study on factors that seemingly impacted student success in Calculus I. In particular, I examined the relationship between final grades and self-reported self-regulatory aptitudes after accounting for incoming math aptitude. Results indicate self-regulatory aptitudes predict final grades above and beyond math aptitude. In addition, measures of self-regulation differed amongst high and under achievers as well as low and over achievers. This indicates self-regulation plays a role in student success. Furthermore, gender differences were present in measures of self-regulation which may be of importance for improving retention of women in STEM.

Keywords: Calculus, Motivation, Self-Regulation

Calculus I is known to be a barrier to success for students desiring a career in science, technology, engineering, and mathematics (STEM) fields (National Academies of Sciences, Engineering, and Medicine, 2016). Recent national data shows that little more than half of students in calculus I receive a grade of an A or B and DFW rates are around 22-38% depending on the type of institution in which the course is taken (Bressoud, 2015). Of particular concern is the number of women who do not persist into calculus II with 20.1% of females switching their calculus II intention at the end of calculus I (Ellis, Kelton, & Rasmussen, 2014).

Research has correlated student self-regulation with final grades (Pintrich, Smith, Garcia, & McKeachie, 1991). In particular, recent studies have shown self-regulation measures can predict exam scores in Calculus I (Worthley, 2013) and a calculus based engineering analysis course (Hieb, Lyle, Ralston, & Chariker, 2015). This suggests that addressing self-regulation factors may be important aspects of the curriculum that could potentially improve success for some types of students. However, there is a gap in the literature regarding achievement group differences in self-regulatory aptitudes. Prior regression models indicate self-regulation predicts grades above and beyond incoming math aptitude when considering the sample as one group (Hieb, et al., 2015; Worthley, 2013). However, when classified into four achievement groups based on performance relative to the median incoming math aptitude and median final grade (see Figure 1), it is not known if achievement groups report the same type of self-regulation.

Furthermore, it remains unclear what role gender may play in the relationship between self-regulatory aptitudes and final grades in Calculus I. Prior studies have shown gender differences among self-regulatory aptitude measures (Pintrich & DeGroot, 1990; Zimmerman & Martinez Pons, 1990). In addition, although prior studies have shown aspects of self-regulation impacts success after taking into account incoming math ability, there is a gap in the literature regarding if a model of success for males would differ from a model for females. Better understanding of differences in performance according to gender and achievement groups can aid in designing interventions that cater to specific student populations. To address these gaps in the literature, three main research questions guided data analysis for the current study:

1) Are gender differences present in self-reports of self-regulation among students enrolled in Calculus 1?
2) Is there a relationship between final grades and self-regulation according to gender?
3) How do achievement groups differ in their self-reports of self-regulation?

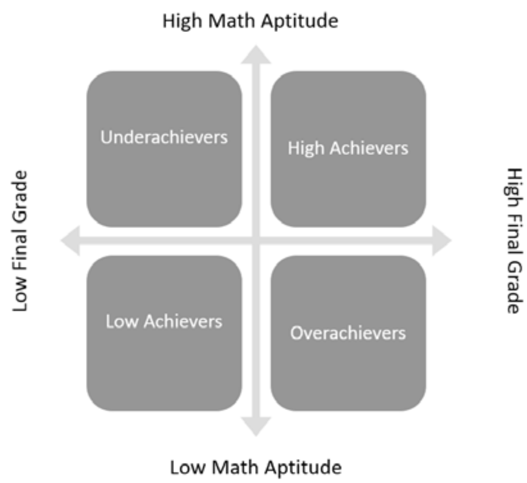

Figure 1. Achievement groups

Theoretical Framework and Literature Review

Broadly, self-regulation involves setting a standard or goal, monitoring progress toward the goal, controlling oneself to make adjustments if needed, and reflecting on one's performance (Pintrich, 2004). Self-regulation is rooted in social cognitive theory, examining reciprocal interactions between the individual, their behavior, and their environment (Zimmerman, 1989). For example, Pintrich and Zusho (2007) argue classroom contexts such as academic tasks and instructor behavior impact students' self-regulatory processes which in turn impacts student outcomes.

This study draws upon Pintrich and Zusho's (2007) and Pintrich's (2004) frameworks for self-regulation. Pintrich and Zusho's model places self-regulation within the context of the classroom. They argue students' personal characteristics and the classroom context impact students' motivational and self-regulatory processes. While some self-regulation models consider motivation to fall under self-regulation, Pintrich and Zusho distinguish motivational processes apart from self-regulatory processes. They argue motivation only becomes self-regulatory when there are active attempts to monitor and control motivation. In Pintrich and Zusho's model, motivational and self-regulatory processes then affect student outcomes. The outcomes then feed back into the model to impact future classroom context, motivation, and self-regulatory processes. According to Pintrich and Zusho's model, interventions to alter the classroom context could lead to changes in motivational and self-regulatory processes. However, it must first be understood which motivational and self-regulatory processes are impacting outcomes.

Pintrich's (2004) framework provides a means of examining motivational and self-regulatory processes within categories. In his framework, Pintrich (2004) places motivational processes under the umbrella of self-regulation. Pintrich classifies self-regulation as occurring in four areas: cognition, motivation, behavior, and environment. In addition, he considers self-regulation to occur over four phases: forethought and planning, monitoring, control, and reflection. While Pintrich acknowledges that self-regulation does not necessarily occur linearly through the phases and some aspects of self-regulation don't neatly fit into one area, thinking of self-regulation in terms of phases and areas does allow for distinction among self-regulation processes.

Pintrich's (2004) framework stems from his work developing the Motivated Strategies for Learning Questionnaire (MSLQ). The MSLQ is a questionnaire designed to measure students' course specific self-regulatory aptitudes (Duncan & McKeachie, 2005). The MSLQ has 15 subscales which Pintrich (2004) later mapped onto his classification framework.

In recent years researchers have used the MSLQ to consider the role of self-regulation in success among calculus students. In particular, some studies have attempted to utilize models that predict student success in calculus considering variables such as self-regulatory factors. For instance, Worthley (2013) and Hieb, et al. (2015) used subscales of the MSLQ in their models. Worthley found MSLQ subscales of test anxiety and self-efficacy for learning and performance were good predictors of first midterm grades when combined with math placement test results. Hieb, et al. found that of the select MSLQ subscales administered to their subjects, time and study environment management, internal goal orientation, and test anxiety were good predictors of exam scores. These studies indicate self-regulatory factors play a role in student success and should be examined in more detail.

Furthermore, studies have shown males and females differ in their mathematics interest and self-efficacy beliefs as early as middle school (Pajares, 2005) and the trend continues into college (Pajares & Miller, 1994). In addition, females maintain higher test anxiety than males (Hong, O'Neil, & Feldon, 2005; Pajares & Miller, 1994). Considering these results, it seems plausible that different gender groups may need attention on different areas of self-regulation. Thus it is necessary to examine whether the impact of self-regulation aptitudes on grades vary by gender.

Method

Participants

All autumn 2016 Calculus I students at a large Midwestern university were invited to participate in the study. Of the 2539 students enrolled in the course on the 15^{th} day of class, 603 consented to have their data be used in research. Among these 603 students, 29 withdrew from the course. Of the 573 remaining students, 36% (*n* = 149) of students had missing data leaving a complete data set for 424 students.

Measures and Procedure

The Calculus Concept Readiness (CCR) assessment (Carlson, Madison, & West, 2015) was administered to students during the first week of the academic semester. The CCR was used as measure of students' conceptual preparedness for calculus. In addition, the CCR provided an incoming math aptitude measure taken at the same time-point for all students. Students' ACT and SAT Math scores were collected from the university's database system. For students with no ACT Math score their SAT Math scores were converted to ACT Math equivalent scores (Dorans, 1999). In order to create a single composite incoming math aptitude score, ACT/SAT math and CCR scores were combined. The composite math aptitude score was computed by transforming scores on the CCR and ACT/SAT math test into z-scores and then summing the scores.

Students completed 12 of the 15 Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) subscales during the fifth week of the semester. The motivation subscales that were used were intrinsic motivation, task value, control of learning beliefs, self-efficacy, and test anxiety. The learning strategy and resources management subscales used were elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, and peer learning.

Final grades as a decimal percentage were collected from the university's learning management system gradebook after the semester was complete and final grades for courses had been submitted.

Results

Gender Differences

A multivariate analysis of variance (MANOVA) was performed to determine gender differences in MSLQ subscale scores. Using a Wilks's Lambda, there was a significant effect of gender on MSLQ subscales, $\Lambda = .800$, $F(12,411) = 8.548$, $p < .001$. The MANOVA was followed up with one-way ANOVAs. Adjusting for Bonferroni's correction, significant differences in gender were found on intrinsic motivation, self-efficacy, test anxiety, critical thinking, organization, intrinsic motivation, and time and study environment (*ps* < .004). Females reported significantly lower intrinsic motivation, self-efficacy, and critical thinking than males. Females reported significantly higher test anxiety, organization, and time and study environment structuring than males.

A hierarchical regression was performed in order to determine predictability of final course grade. Math aptitude was entered in the first step. Then all ten MSLQ subscale scores were entered in the second step via forced entry. Finally, gender was entered as the third step. In the first step, math aptitude was a significant predictor of final grades, $R^2 = .352$, $F(1,422) = 228.82$, $p < .001$. In the second step, the MSLQ subscales were added to the model and contributed a significant change in $\Delta R^2 = .136$, $F(12,410) = 9.076$, $p < .001$, for a total model $R^2 = .488$. The third step, entering gender, did not result in a significant change in R^2 ($\Delta R^2 = .002$, $F(1,409) = 1.534$, $p = .216$). This final step indicates that after accounting for math ability and MSLQ scores, gender does not significantly predict final grade.

In addition, a secondary hierarchical linear model was applied to determine if the same hierarchical linear model of math aptitude and MSLQ subscales to predict final grades could be used for both men and women. Comparing the fit of the models using Fisher's Z-test ($z = 1.45$, $p = .147$) and the structure of the models using Steiger's Z, ($Z_H = -2.11$, $p = .034$) the same hierarchical linear model can be used for both men and women ($R^2 = .488$, $p < .001$).

Achievement Level Differences

In order to determine how self-regulation may differ amongst achievement groups, students were categorized into four clusters. Students were ranked according to both their math aptitude and final grade scores. Students below the median in math aptitude and final grade were categorized as low achievers. Overachievers were those students below the median in math aptitude but above the median in final grade. Students above the median in math aptitude but below the median in final grade were categorized as underachievers. Finally, students above the median in math aptitude and above the median in final grade were categorized as high achievers (Figure 1). There were 167 low achievers, 73 overachievers, 67 underachievers, and 176 high achievers in the sample.

Results

A multivariate analysis of variance (MANOVA) was performed to determine achievement group differences on MSLQ subscale scores. Using a Wilks's Lambda, there was a significant effect of achievement group on MSLQ subscales ($\Lambda = .699$, $F(36,1209) = 4.336$, $p < .001$). The MANOVA was followed up by post hoc Hochberg's GT2 tests and confirmed with Games-Howell tests. Group differences at a $p < .05$ level are indicated in Figure 2. When comparing to low achievers the post hoc tests indicate both high achievers and overachievers have greater intrinsic motivation, task value, and self-efficacy but lower test anxiety. Only high achievers have greater metacognitive self-regulation and control of learning beliefs than low achievers. When comparing underachievers, both high achievers and over achievers have greater task value, self-efficacy, time and study management, and effort regulation. Only high achievers have greater intrinsic motivation and metacognitive regulation but lower test anxiety than underachievers. At a $p < .05$ level, no statistically significant differences were found between high achievers and over achievers or under achievers and low.

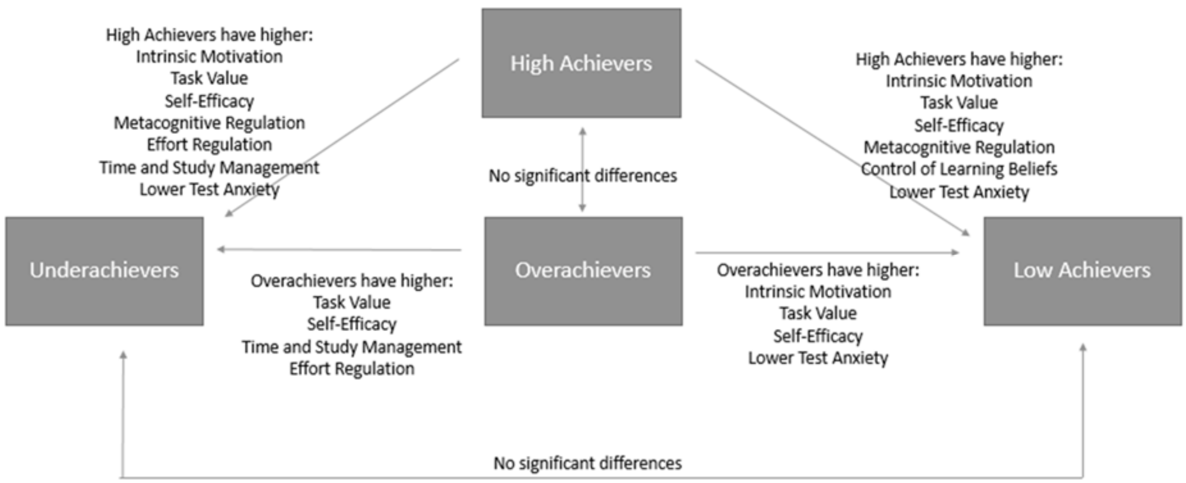

Figure 2. Differences in MSLQ subscales by achievement group

Discussion

Results indicate that the CCR adds significant predictive power when used in combination with ACT/SAT math scores. Combined, these scores can account for 32% of variance in final grades. In addition, adding MSLQ measures of self-regulation, the model accounts for 48% of variance in final grades. This indicates that self-regulation attributes are important for success in calculus I. Incoming math aptitude and pre-requisite knowledge is not enough to ensure success.

Results show self-regulation predicts final grades the same in males and females. However, females reported lower intrinsic motivation, self-efficacy, and time and study environment management, as well as higher test anxiety than males. This indicates addressing motivation and self-regulation for females may be important to retaining females in STEM.

In addition, differences in MSLQ scores amongst achievement groups indicate different populations have different self-regulatory needs. While both high achievers and underachievers came in with above median math aptitude, underachievers ended the course with a grade below the median. Differences in self-regulation may account for the underperformance of underachievers as these students differed significantly on several MSLQ subscales compared to high achievers. Furthermore, low incoming math aptitude does not necessarily doom a student to failure. Self-regulation may again play a role as overachievers and low achievers scored significantly differently on several MSLQ subscales. Data indicates addressing self-regulation in low and under-achievers may promote success in calculus.

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