Studying Mathematics in High School and College:

Summer Bridge Program Student Beliefs

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***Abstract*—Prospective engineering students often have difficulty with study expectations when transitioning from high school to college. Mathematics is particularly challenging for those who have been successful in high school without needing to study. Engineering mathematics college courses tend to cover twice the volume of material in 60% of the class time of high school mathematics courses. Thus, the need for outside study time is increased drastically, and the time to absorb and practice concepts and skills is reduced. Surveys from students in a summer precalculus program revealed that they understood that their strategies for success in mathematics should change as they transitioned to college. However, they often failed to begin the change while participating in the summer program designed to increase their algebra and precalculus skills in preparation for engineering calculus. The research questions for this study are:**

1) **For prospective engineering students in a summer precalculus bridge program, how did their expectations of college mathematics study compare with their expectations of high school mathematics study?**
2) **How well do prospective engineering students in a summer precalculus bridge program begin to change their study habits in preparation for engineering college mathematics?**

Keywords—bridge program; precalculus; engineering calculus; student beliefs

I. Introduction

Success in college mathematics is crucial to many majors, especially STEM majors, which naturally includes engineering. But students often struggle to complete the calculus sequence of courses they need for their majors [1] [2]. The first year of college calculus has been predictive of persistence in engineering majors [3]. In addition, students who needed precalculus strengthening for college calculus graduated at a rate of about 70%, while those who were able to enroll in calculus the first semester graduated at a rate of about 80% after four years [4]. The good news is that success in mathematics increases motivation for additional success [5]. Thus, the first challenge is to enable students to be successful in the first college mathematics course.

It has long been an expectation from college instructors that undergraduate students need to spend two or more hours working outside of class for each hour spent in class. However, students often do not spend much time. The problem may not be a poor work ethic, but it could be that students do not know how to structure and manage their study time. These ideas were part of a 1998 study [6]. Almost 20 years later, the problem was evidently still prevalent. A challenge was given to a group of students to use a study guide that took a different perspective in order to change student beliefs and actions to become more active in the process and make their study time more effective

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[7]. Student beliefs about their ability to be successful in mathematics is also part of the equation [8]. If they believe their success is because they are smart or lucky, they may not be inclined to study efficiently or effectively. Differences in whether students approach study material as cursory reading or even something to be memorized rather than something to be well understood also have an effect on their success in mathematics. Encouraging students to expend effort in study improved their persistence in college [9][10]. Teaching students how to study effectively before they entered college gives them a more solid foundation and serve them well in college [9][6]. If strong connections to prior mathematical knowledge are not made and conceptual understanding is not developed by the first college mathematics courses, even though students may do well in the earlier courses, success in the later courses is unlikely [10]. Teaching methods that aid students in developing conceptual understanding and connections among mathematical ideas have been shown to contribute to student success in mathematics [8].

Various interventions have increased mathematics achievement, motivation, and perseverance [11-16]. Convincing students to participate in bridge program, which have been primarily voluntary, has been challenging [17]. They often believe they already know the material regardless of placement exam scores [18]. However, the overall success for students who participate in bridge programs in positive [19-21]. The first bridge programs were face-to-face, but asynchronous online formats emerged in about 2007. Initially, they were not very successful [20], but new technologies for synchronous online teaching and learning have shown success [22] [23]. Bridge programs with live, online tutors can strengthen mathematics skills for engineering students [24].

We have seen some success in improving mathematics placement exam scores and better success in the calculus sequence, but we are also interested in strategies in addition to improving the mathematics knowledge and skills. Characteristics of students, their confidence in mathematics, and beliefs and practices related to mathematics study could all have some impact. Learning more about student characteristics, beliefs about studying mathematics, and habits in mathematics study could provide insight that leads to program additions or changes that would help students be more successful in their college studies, particularly in mathematics. Survey questions that address some of the aspects from the literature were utilized in this study. The research questions for this study are:

1) For prospective engineering students in a summer precalculus bridge program, how did their expectations of college mathematics study compare with their expectations of high school mathematics study?
2) How well do prospective engineering students in a summer precalculus bridge program begin to change their study habits in preparation for engineering college mathematics?

II. Methodology

For this study, we focused on one aspect of the expectations for mathematics at the college level, time spent in pursuit of mathematics study. Incoming freshmen at a large southwestern university were offered an opportunity for a summer online precalculus intervention to prepare for engineering calculus. Students had to take the Mathematics Placement Exam (MPE) and make the cut score of 22 correct out of 33 in order to register for the first engineering calculus course. If students did not meet the cut score, they had two choices: 1) register for the precalculus course in the fall, or 2) participate in the Personalized Precalculus Program (PPP) during the upcoming summer and raise their MPE scores to the required level.

The PPP is a fully online precalculus program. However, it is a blend of synchronous and asynchronous elements. Materials available to the students included instructional videos with exemplary problem solutions, an online textbook, and practice problems to solve, including free response questions. Students were required to meet in small groups of about 20 students with an online tutor. Students were expected to spend 10 hours per week for 3 weeks in small groups with the online tutor. After a few minutes of instruction, they were separated into virtual breakout rooms singly or in pairs to work on mathematical problems on the whiteboard. The tutor circulated through the rooms and asked and answered questions that facilitated student learning. Work from each room's whiteboard was saved and shared in the main room when the class reconvened. The tutor then discussed similar difficulties that were encountered in the breakout rooms and debunked misconceptions in the mathematics.

Participants in this study were incoming freshman engineering majors who chose the PPP and completed one or more of three surveys during the three-week intervention ($N = 300$). The survey questions of interest to this study (variable name) were:

<u>Week 1 Survey</u>

To be successful in calculus at Texas A&M University, I think I will need to spend the following amount of time per week studying mathematics outside class. (CalcTime)

1. Less than 30 minutes per week
2. 30-60 minutes per week
3. 60-90 minutes per week

4. 90-120 minutes per week
5. More than 120 minutes (two hours) per week

Week 2 Survey

About how long did you spend on the PPP in the past week? (TimeS2)

1. Less than 6 hours
2. 6-7 hours
3. 8-9 hours
4. 10-11 hours
5. More than 11 hours

Week 3 Survey

While in high school, I spend the following amount of time per week studying mathematics. (TimeHS)

1. Less than 30 minutes per week
2. 30-60 minutes per week
3. 60-90 minutes per week
4. 90-120 minutes per week
5. More than 120 minutes (2 hours) per week

While at Texas A&M University, I expect to spend the following amount of time per week studying mathematics outside of class. (TimeColl)

1. Less than 30 minutes per week
2. 30-60 minutes per week
3. 60-90 minutes per week
4. 90-120 minutes per week
5. More than 120 minutes (2 hours) per week

About how long did you spend on the PPP in the past week? (TimeS3)

1. Less than 6 hours
2. 6-7 hours
3. 8-9 hours
4. 10-11 hours
5. More than 11 hours

Descriptive statistics (e.g., N, minimum, maximum, mean, mode, standard deviation) were calculated on the study variables. Correlations between variables were calculated with SPSS, and paired sample *t*-tests were calculated for time spend on PPP on the second and third surveys.

III. RESULTS

The means and standard deviations for the study variables are given in Table 1. Note that the mean values do not represent actual time, but the average of the choices in the survey, coded as 1 through 5 ("Less than 30 minutes per week" through "More than 120 minutes (2 hours) per week"). In the first survey, for the time they expected to spend in college calculus (CalcTime), 208 out of 260 (80%) chose either "90-120 minutes per week" or (More than 120 minutes (2 hours) per week). For the time they reported spent on the PPP during the second survey (TimeS2), the mode was still "More than 120 minutes per week" but only 37% made that choice, and only 56% chose either "More than 120 minutes per week" or "90-120 minutes per week." In striking contrast, 30% of participants reported spending an equivalent amount of time on their high school mathematics study. In the third survey, student expectations of the time they would need to spend studying mathematics outside of class, 65% chose "More than 120 minutes per week" while 85% chose either "More than 120 minutes per week" or "90-120 minutes per week." These results indicated that their perceptions of the amount of time required for college mathematics success increased slightly during the PPP intervention. However, the time they spent on the PPP did not increase.

TABLE I. STUDY VARIABLES MEANS AND STANDARD DEVIATIONS

	N	*Mean*	*SD*	*Mode*	*% Mode*
CalcTime	260	4.30	0.83	More than 120 minutes per week	52%
TimeS2	186	3.62	1.32	More than 120 minutes per week	37%
TimeHS	151	2.87	1.19	30-60 minutes per week	31%
TimeColl	151	4.46	0.85	More than 120 minutes per week	65%
TimeS3	151	3.33	1.40	More than 120 minutes per week	29%

Means for the variables related to time students expected to spend on college calculus (CalcTime, TimeColl), time they spent on the PPP in weeks 2 and 3 (TimeS2, TimeS3), time they reported spending on high school mathematics study outside class time (TimeHS) are shown in Figure 1. Figure 2 illustrates the statistically significant difference ($p < .05$) in student expectations of time needed to succeed in college mathematics and time they spent in high school mathematics. Although students recognized the difference, Figure 3 shows that in the PPP, they did not begin to increase their study time through the course, even though the topics addressed increased in difficulty as they progressed. Even over the short period of the three-week PPP, and even though they improved their mathematics skills, students did not persist in spending sufficient time to thoroughly master the material.

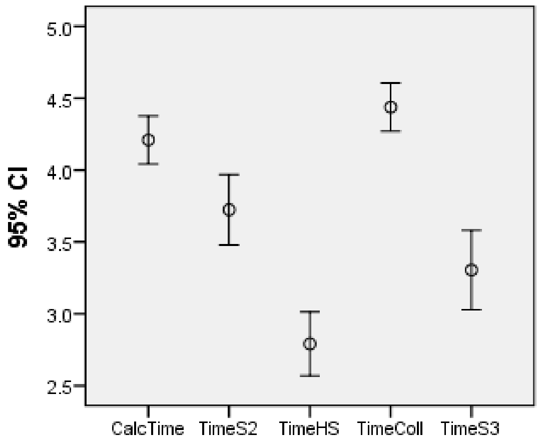

Fig. 1. Means and 95% CI for Variables.

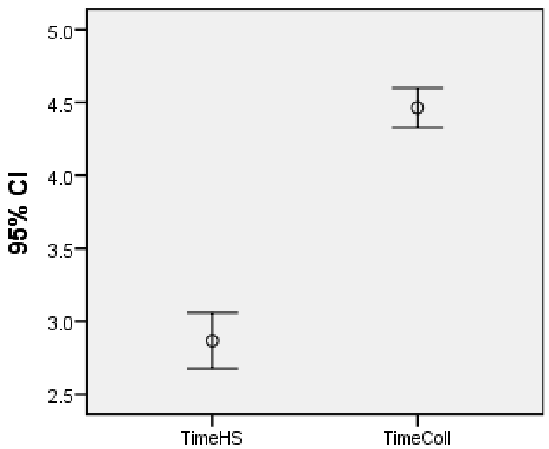

Fig. 2. Means and 95% CI for High School Time and expected College Time.

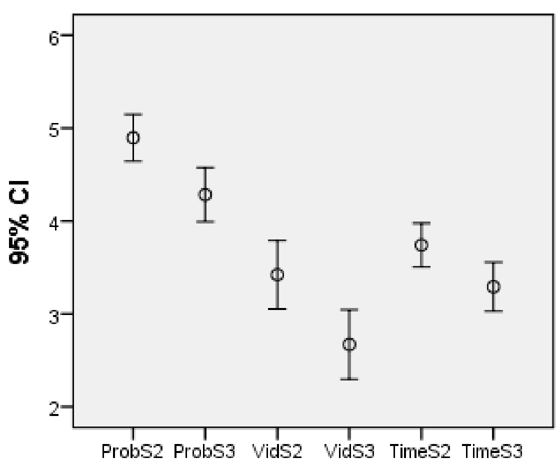

Fig. 3. Means and 95% CI for Number of Problems, Number of Videos, and Time Spent in Weeks 2 and 3.

IV. Discussion

If the results from this study are typical of incoming college freshmen, there is a need for assistance in learning how to study college mathematics, establishing good study habits, and self-regulation in learning. Content knowledge background is necessary but not sufficient for success in college calculus. Either interventions need to include strategies for success in college mathematics or colleges should provide support for students. Although many colleges do have one-hour courses for this purpose, they are recommended for the most at-risk students rather than being widely recommended or required. Thus, many freshmen soon find themselves in the unenviable position of needing to excel on the final exam in order to raise their grades to an acceptable level. This is unlikely to occur, and students often are not realistic about the probability of success at that point. Mathematics departments might consider laying out some strategies that all instructors will discuss for a few minutes each class period in order to remind students how to stay on track for success.

Much has been written about teaching styles and methods, and there is considerable evidence to show that teaching strategies that encourage student depth of knowledge. Inquiry based strategies, such as project-based learning are engaging to students because they offer opportunities to understand mathematics within the broader picture of the interdisciplinary nature of real-world problems. These teaching methodologies should be encouraged at all levels of education. However, at some point in their educational journey, especially as they reach adulthood in the college environment, students must take the responsibility to seek out opportunities for learning and strategies and methods of study that are conducive to their own learning. Teachers at the high school and college level could support students by taking time to discuss and how to study mathematics as students advance in their studies, encouraging students to find successful strategies. Students need to understand the difference that often occurs in the transition to college level mathematics study, including the increase in time for preparation, concentration of the study, and volume of materials to be learned in a short time frame. Thus, a combination of good teaching strategies and effective study habits will enable students to gain the maximum benefit of their learning opportunities in high school, college, and throughout their lives.

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