College Freshman Beliefs About Studying and Learning Mathematics: Results from a Summer Engineering Calculus Bridge Program

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Prof. G. Donald Allen, Texas A&M University

Dr. Allen has been a professor of mathematics at Texas A&M University for more than two decades. He is currently Director of the Center for Technology-Mediated Learning in the Department of Mathematics. His mathematical research has been in the areas of probability, functional analysis, numerical analysis, neutronics, and mathematical modeling. His education research is in technology in survey design and other subjects. Allen has co-developed an online calculus course and online texts in linear algebra and the history of mathematics. In addition, he has co-developed a fully online master's of science degree in mathematics, one of only two nationally, and the only one specifically designed for teachers. For the master's program, he developed more than seven online courses. Recently, Allen co-developed a "course-in-a-box" pre-calculus course by combining content, pedagogy, assessment, videos, animations, and interactivity. Currently, he is leading a multi-institutional course redesign project in Math 1324 for the THECB. He is also active in a NSF funded GK-12 project with rural middle schools.

Allen is editor of the Math/Science-Online Newsletter and a consulting editor for Thomson Learning. He is also associated editor for the Schools Science and Mathematics Journal and the Focus on Mathematics Pedagogy and Content. Allen, with more than 50 publications, has given nearly 40 professional development workshops and over 150 seminars throughout the U.S. and Europe. In particular, he has participated in numerous professional development workshops primarily for Texas high school teachers, including those in technonlogy, algebra, pre-calculus, and problem solving. He has also developed a number of educational Flash interactive applets for teaching at various levels of mathematics, physics, and statistics.

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Ali Bicer was a high school mathematics teacher in Turkey for three years. He came to Texas A&M University from Turkey for his doctoral work after graduating from Belal Bayar University in 2006. His Ministry of National Education Scholarship allowed him to complete his Masters in Mathematics Education in 2012 and his Ph.D. in Mathematics Education in 2016, both at Texas A&M University. Upon graduation in 2016, he had the highest number of publications in the program so far. He served as the STEM Summer Camp Assistant Director for two years. In addition, he taught students in the camp as well as assisting with teacher professional development. His honors include the Lechner Scholarship and the College of Education Graduate Strategic Support Scholarship. As a graduate student, he distinguished himself through his extensive publications on STEM teaching and learning and has participated in the writing of several grant proposals. He presented his research at several educational research conferences including AERA, NCTM, and SERA as well as having papers in proceedings of FIE and AAEE in engineering education. He earned several publications including journal articles, book chapters, and conference proceedings. He is currently teaching mathematics education courses and conducting rigorous research in the field as a Post-Doctoral Researcher at Texas A&M University. With his background, he is on track to become a successful mathematics educator and scholar.

Prof. Jim Morgan, Charles Sturt University

Jim Morgan is the father of two daughters and the spouse of an engineer. Before joining Charles Sturt University as Professor of Engineering and Inaugural Course Director in 2015, he was on the faculty in civil engineering at Texas A&M for over 30 years. Jim has been active in the freshman engineering program at A&M for nearly 20 years; was an active participant in the NSF Foundation Coalition from 1993 to 2003; also has received funding for his engineering education research from the Department of Education FIPSE program and from the National Science Foundation CCLI program. He is active in the American Society for Engineering Education, is past chair of the Freshman Programs Division, currently serves on the steering committee. In addition to his teaching in engineering, Jim served several years as Co-Director of the Eisenhower Leadership Development Program in the Center for Public Leadership at the George Bush School of Government and Public Service; and also served as director of Aggie STEM with funding from the Texas Education Agency and the Texas Higher Education Coordinating Board.

Vanessa Mae Warren, Texas A&M University

Vanessa Warren is a Biochemistry and Genetics major and a freshman undergraduate research assistant at Texas A&M University. Her research interests include mathematics teaching and learning and teacher professional development for STEM education.

Dr. Luciana Barroso, Texas A&M University

Luciana R. Barroso, Ph.D., is an Associate Professor of Structural Engineering in the Department of Civil Engineering, in the Dwight Look College of Engineering at Texas A&M University. Luciana has been with Texas A&M University since 1999, and in that time has taught multiple different courses ranging from the freshman to graduate levels. She has been active in academic program and curriculum development from the department level to the university level, where she served as co-chair of the Quality Enhancement Plan (QEP) committee that determined the academic course of actions to be taken over the next accreditation cycle to addresses critical issues related to enhancing student learning. She has received funding for her engineering education research from the Department of Education FIPSE program and from the National Science Foundation (NSF) CCLI program. She is co-Director of the Aggie STEM Center that provides professional development to K-12 teachers. Her research interests include structural health monitoring and control, structural dynamics, earthquake engineering, and engineering education.

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Abstract

Many incoming college freshman struggle with learning to study and prepare for college examinations in mathematics. High performing high school students often easily succeeded in their mathematics courses while spending minimal time studying the subject. The strategies they used do not always transfer well to the university environment, and they must learn to prepare for assessments over larger amounts of material in a shorter time period. A bridge program was implemented to support incoming freshmen whose mathematics understanding and skills were weak, based on their Mathematics Placement Exam (MPE). Surveys were conducted each week of the three-week intervention to determine student beliefs about what study strategies they believed served them well in high school mathematics, what strategies they expected to use in college, and how much time they anticipated spending on their mathematics studies in the bridge program and in college calculus courses. Students spent 36 hours during the 3-week period in small groups with an online tutor. In addition, they had online practice quizzes, instructional videos, and an online textbook. They were given the MPE again at the end of the program. If they increased their scores to meet the cut score of 22 out 33 correct, they were permitted to enroll in engineering calculus I. This study examines their responses to the surveys during the bridge program and their grades, including any correlations that exist among the variables.

Introduction

As technology advances continue to grow rapidly, there remains a need for a diverse engineering workforce throughout the world. Most engineering majors rely on a strong mathematics foundation. Specifically, being successful on college calculus courses has been crucial to earn an engineering degree [1]. However, most engineering freshmen entered college without having necessary mathematical abilities [2]. Therefore, students who did not have the necessary mathematical abilities to be successful in engineering courses needed help to pursue their engineering majors and complete their engineering degrees. In order to retain and support engineering majors, many universities have offered bridge programs in mathematics for students [3][4]. Such programs were common in the 1990's and have increased again recently as the need has been recognized widely. Bridge programs aimed to increase engineering students' retention by strengthening their mathematical competencies. There are many types of bridge programs in different disciplines, especially science and mathematics. Bridge mathematics programs were more common in mathematics than science and other disciplines because mathematics has long been considered the gatekeeper for college [5]. The majority of bridge programs have been voluntary and sponsored by universities and grant programs. Universities struggled with convincing their engineering students to participate in bridge programs [6]. Universities can increase the retention of engineering freshmen rather than losing them right after they faced difficulties to pass the mathematics placement exam. Mathematics background for engineering majors is an important consideration, and many students who aspire to become engineers struggle in college engineering mathematics courses, even when they were easily successful in high school. There are many factors that can play a part in college mathematics success. For example, adjusting to the college environment, learning self-regulation of class attendance and study, developing study habits for mathematics courses that are intense and compact, and rigorous. Other factors include motivation, self-discipline, content knowledge, and attitude towards mathematics. A strong statistically significant correlation was found between students' calculus achievement and their attitudes towards mathematics. This meant the more positive attitudes towards mathematics engineering students had, the more successful they became in engineering calculus [7]. Students who participated a bridge program were asked their beliefs and perception about studying and learning mathematics and their answers revealed that engineering freshman believed the bridge program helped them to become and stay more successful in engineering calculus courses [8].

The purpose of this paper is to answer the research questions:
1) How do incoming college freshman beliefs about studying and learning mathematics affect their participation in a summer precalculus bridge program?
2) How well do incoming college freshman beliefs about studying and learning mathematics relate to their grades in engineering calculus?

Methodology

Incoming freshmen at Texas A&M University are required to take a Mathematics Placement Exam (MPE) before registering for their courses. The MPE consisted of precalculus problems on topics such as simplifying algebraic expressions, exponents, graphing functions, logarithms, and trigonometry. A score of 22 out of 33 problems correct was required in order to enroll in the first engineering calculus course. Students who scored below 22 were required to take a precalculus course in the fall, delaying their entrance into the first engineering course that required completion of or concurrent enrollment in the first calculus course. The mathematics department developed a summer precalculus bridge program to help retain prospective engineering majors by increasing their knowledge and skills in algebra and precalculus topics in preparation for engineering calculus. Students who participated in the Personalized Precalculus Program (PPP) were allowed to retake the MPE after the program and could then enroll in engineering calculus if the met the cut score. The PPP consisted of asynchronous online resources including instructional videos, an online textbook, and practice problems, housed in WebAssign. In addition participants were required to spend 30 hours during the program in small groups with an online tutor. The online environment features included VOIP for participants to communicate with headsets, a virtual whiteboard to work problems, and virtual breakout rooms for participants to work individually or with partners as they completed problems assigned by the tutor. Participants in the PPP during the summers of 2013, 2014, and 2015 were given a survey asking them their perceptions about the program and how it affected their content knowledge and problem solving abilities. They were asked about their strategies for learning mathematics in high school, their time expectations for mathematics study in college, and study strategies they expected for college. Multiple choice questions asking the level of agreement with statements used a 4-point Likert scale in order to force participants to consider their responses, not allowing them to make a choice of "neutral" for each question. Correlational analysis was conducted on the grade in precalculus or engineering calculus I the first semester after participation in the PPP, gender, ethnicity, and survey responses, including the following questions:

How many online tutoring sessions, on average, did you attend per week? (0-5)

Did you complete the entire WebAssign Personalized Study Program?

In trigonometry, I believe I am best at

- Finding unknown sides and/or angles in common triangles, e.g., 3-4-5 triangles, right triangles with a 45-degree angle, or right triangles with a 30-degree angle.
- Finding unknown sides and/or angles in non-right triangles
- Applying trigonometric identities
- Solving trigonometric equations

In trigonometry, I believe I need the most improvement in

- Finding unknown sides and/or angles in common triangles, e.g., 3-4-5 triangles, right triangles with a 45-degree angle, or right triangles with a 30-degree angle.
- Finding unknown sides and/or angles in non-right triangles
- Applying trigonometric identities
- Solving trigonometric equations

I have memorized properties, including trigonometric values, for common triangles, e.g., 3-4-5 triangles, right triangles with a 45-degree angle, or right triangles with a 30-degree angle and can apply my knowledge in solving problems (4-point scale: strongly agree, agree, disagree, strongly disagree)

I have memorized common trigonometric identities (e.g., $\tan^2 + 1 = \sec^2$) and can use them to prove trigonometric identities and solve trigonometric equations (4-point scale)

Which of the following most accurately describes how you learned to solve mathematics problems in high school?

- I memorized how the teacher showed us how to do specific types of problems and then applied these approaches to similar problems on the exams.
- I found a small number of general principles, learned them well, and applied these principles to solve all the exam problems.
- I read the textbook and used what I learned to solve exam problems.
- I worked in a study group where we taught each other to solve different types of problems.

Which of the following most accurately describes how you expect to master calculus in college?

- I will memorize how the teacher showed us how to do specific types of problems and then apply these approaches to similar problems on the exams.
- I will find a small number of general principles, learn them well, and apply these principles to solve all the exam problems.
- I will practice a large number of homework problems on a regular basis, and then practice will enable me to solve the exam problems.
- I will read the calculus textbook and use what I learned to solve exam problems.
- I will study in a group where we will teach each other to solve different types of problems.

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.

- Less than 30 minutes per week
- 30-60 minutes per week
- 60-90 minutes per week
- 90-120 minutes per week
- More than 120 minutes (two hours) per week

Which of the following most accurately describes how I will study calculus in college?

- I will memorize how the teacher showed us how to do specific types of problems and then apply these approaches to similar problems on the exams.
- I will find a small number of general principles, learn them well, and apply these principles to solve all the exam problems.
- I will practice a large number of homework problems on a regular basis, and then practice will enable me to solve the exam problems.
- I will read the calculus textbook and use what I learned to solve exam problems.
- I will study in a group where we will teach each other to solve different types of problems.

I believe the way I studied mathematics in high school will enable me to earn an A or B in college calculus. (4-point scale: strongly agree, agree, disagree, strongly disagree)

Which of the following most accurately describes how I will need to study college calculus to earn a grade of A or B?

- I will memorize how the teacher showed us how to do specific types of problems and then apply these approaches to similar problems on the exams.
- I will find a small number of general principles, learn them well, and apply these principles to solve all the exam problems.
- I will practice a large number of homework problems on a regular basis, and then practice will enable me to solve the exam problems.
- I will read the calculus textbook and use what I learned to solve exam problems.
- I will study in a group where we will teach each other to solve different types of problems.

Results

Descriptive statistics were used to examine the survey results, and several interesting issues were found among the 307 participants who answered the survey. When asked about their best trigonometry skills, 63.5% were at the level of working comfortably with special right triangles as opposed to non-right triangles, applying trigonometric identities, or solving trigonometric equations. When asked about their least skill abilities, 44.0% indicated that they could not apply trigonometric identities, and an additional 38.1% said they could not solve trigonometric equations. Only 1.3% of the students claimed to know their trigonometric values and were able to work with special right triangles.

The majority of students (59.9%) indicated that their best strategy for learning mathematics in high school was to memorize how the teacher did certain problem types and applied those methods to their test problems. Less than one-fifth of the students (18.6%) believed that strategy was the best one for their study of college mathematics, while almost one-third (29.3%) believed the best way to master college mathematics was to work a large number of homework problems on a regular basis so that they could ensure success in solving problems on the exam. Thus, approximately half of the students chose a strategy that involved learning or practicing certain types of problems rather than focusing on principles that could be applied in various types of problems.

While it was encouraging to see that students believed they need to spend considerable time on the study of mathematics, their expectations still fell short of the long-time norm for college study. More than half (54.1%) expected to spend 1.5-2 hours per week on mathematics homework, and none of them expected to spend more than 2 hours per work on their mathematics study. This was disturbing because, although students do not seem to spend adequate time studying, it might be expected that they would recognize that the rigors of college would lead to a greater study time commitment. The weekly average of 1.5-2 hours per week is less than the time they spend in class, and averages to less than 30 minutes per day over a 5-day week. In addition, more than half (52.5%) of the students believed the strategies they used in high school would be effective in enabling them to earn an A or B in college mathematics.

There were several positive correlations, but the most interesting was that students who indicated they knew their trigonometric identities were more likely to attend more PPP sessions and complete the online practice. There were a number of statistically significant correlations between the questions asked, but these revealed no important information. Many of the choices were categorical data and could not be ranked with numbers to indicate levels. Although it was expected that student beliefs would relate to their grades, there was not a strong indicator for any single belief to relate strongly to their beliefs.

Discussion

Although the PPP has been successful in raising student MPE scores and enabled at-risk students who participated to do at least as well as their peers who did not participate, there are clearly some other factors at stake in enabling students to be successful in engineering mathematics. Students arrive on campus with a lack of understanding of the commitment of time and effort that they must make in order to be successful in engineering majors, including the study of mathematics. Filling the content knowledge gaps is challenging but doable if students are willing to work to achieve their goals. However, the root causes of their knowledge deficiency must be addressed. If their background knowledge is increased, but their expectations are unreasonable, and their study habits remain weak, they will likely drop again in their success levels in college mathematics. The factors are complex, and more information is needed to fully understand the relationships between student beliefs and grades. Interviews or focus groups are recommended, along with qualitative analysis to learn more about these factors and determine ways to address them for greater student success. Bridge programs for incoming freshmen need to include instruction and encouragement in developing good study habits that will enable them to be successful in mathematics study.

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