AC 2011-1874: EFFECT OF MATH COMPETENCY ON SUCCESS IN ENGINEERING SCIENCE COURSES

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Effect of Math Competency on Success in Engineering Science Courses

Abstract

A few decades ago, only students with a strong math and science background would seriously consider pursuing a career in engineering. Today, with the exception of highly selective colleges – it is common among many engineering programs around the nation to admit students at varying levels of math competency. At the University of Wisconsin-Platteville, many students begin in the pre-engineering program if they enter college with a perceived low level of math competency reflected by poor performance in the math placement test. Consequently, they end up spending several semesters taking remedial math courses before beginning the calculus sequence and getting accepted in the engineering program. In an effort to understand and serve students better, the effect of math competency on their success in engineering science courses and possible retention in the program is being studied through a survey. The results of this survey are expected to provide us with a better insight into the math preparedness of our high school recruits. The collected data indicates that there is a direct correlation between perceived math preparation and confidence level in early engineering courses. The data from this survey will be used in our college to formulate an effective intervention strategy. In this paper, the details of the survey and the results are presented. Possible suggestions for future directions are also discussed.

Introduction

Until recently, the perception was that only students with a strong math and science background would seriously consider pursuing a career in engineering. Today, with the exception of highly selective colleges – it is common among many engineering programs around the nation to admit students at varying levels of math competency. Many engineering educators believe that students have to meet or acquire a certain level of math competency in order to survive the rigors of an engineering program. Because they are mandated to accept a certain percentage of resident students, engineering programs at state universities are often facing the challenge of dealing with students at lower than ideal levels of math readiness.

At our university, students typically begin in the General Engineering (GE) program and then matriculate into one of seven engineering majors after successfully completing core courses with required core grade point average (CGPA) in math, physics, chemistry, and the engineering sciences. Students begin in the pre-engineering program if they arrive at the university with a perceived low level of math competency reflected by poor performance in the math placement test or a low score in the math section of ACT. Reasons for poor math placement scores may include not taking the placement test seriously, not having had four years of math in high school or having completed four years and never gaining confidence. Consequently, they end up spending several semesters taking remedial math courses before beginning the calculus sequence. In an effort to understand and serve students better, the effect of math competency on their success in engineering science courses and possible retention in the program is being

studied. As part of the study, more than 700 students enrolled in various GE courses have been surveyed. The courses range from introductory level courses such as Engineering Success Skills and Engineering Graphics to Statics, Dynamics, Mechanics of Materials and Basic Thermodynamics.

The survey was conducted entirely on a self reporting basis – students reported their own perception of their math competency level. They were asked to rate their math preparedness for all the introductory engineering and engineering science courses. If they had rated themselves low, they were asked about steps they had taken to address their deficiency. If they were having difficulty in a math class, they were asked to choose from a variety of possible reasons with the hope that they would really examine where the difficulty was coming from and seek help to address the issues. Since many states require only two years of math for high school graduation [1], students were asked about the highest level math class they had taken in high school and how long before they entered college they had taken the last math course. They were also asked about their ACT math score, math placement score, their first math course in college, if they had to repeat any math courses in college and what were the biggest challenges in the first math course in college. Finally, students were asked about their confidence and performance/satisfaction level in the courses in which they were currently enrolled.

The results of this survey are expected to provide us with a better insight to the math preparedness of our high school recruits. Results indicate that there is a direct correlation between perceived math preparation and confidence level in early engineering courses. The data from this survey will be used in our college to formulate an effective intervention strategy. In this paper, the details of the survey and the results are presented.

Survey Instrument

The goal was to see if we could establish a correlation among factors relating to math experiences and competencies of our students and their placement and eventual success in engineering science courses. Therefore, we decided to ask students surveyed to self report several items - the highest level math course they took in high school and how long before entering college they had completed this course, their Math Placement Level score (MPL) when entering college, their ACT Math score, the first math course they took in college, and if they had to repeat any college math courses. In addition, we asked them to rate their math skills before taking an engineering science course and if they felt that they were adequately prepared for the course, along with their expected performance. They were also asked to respond to a very similar question with regard to their first math course taken at the university. Students were asked to write about their biggest challenges in both instances and how they managed them. Finally, they were asked for their suggestion on what they perceived could be done differently for both high school and college math courses.

Survey Results and Discussion

Responses collected from 719 students enrolled in various General Engineering (GE) courses offered between spring 2008 and spring 2010 were analyzed. The courses included introductory

courses such as Engineering Success Skills, Introduction to Engineering Projects, Engineering Graphics, Engineering Modeling and Design and engineering science courses such as, Statics, Dynamics, Mechanics of Materials, and Basic Thermodynamics.

The composition of the survey population by class standing is shown in Figure 1 below. As expected, there were more freshmen and sophomore students in the survey pool than juniors and seniors. More than 42% of the students were sophomores. Students are typically enrolled in multiple General Engineering (GE) courses during their freshman and sophomore years before they declare their engineering major. They could be enrolled in a GE class during their junior and senior years if it is taken as an elective, for example, dynamics or thermodynamics for civil, electrical or industrial engineering majors.

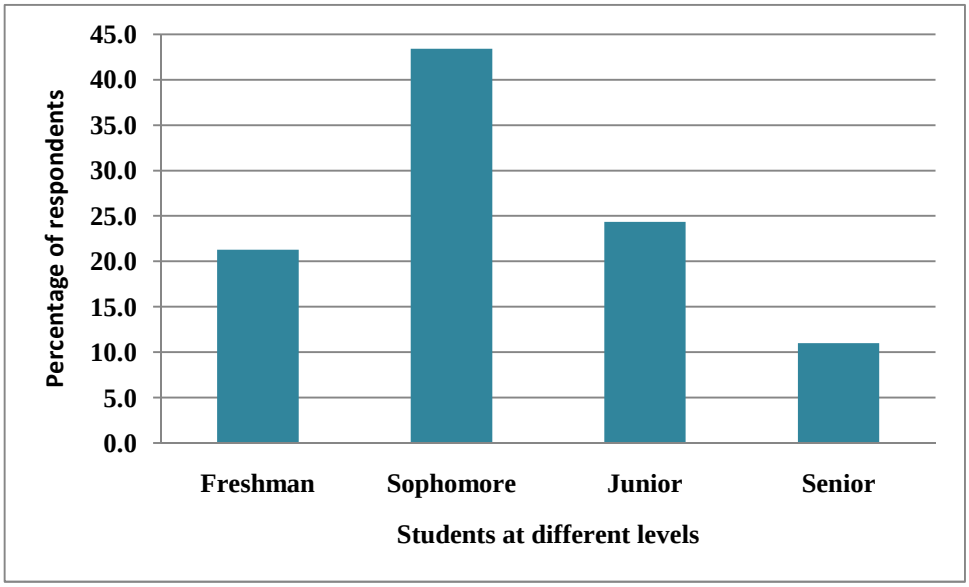

Figure 1: Students surveyed at different levels

A significant majority of the surveyed students completed Pre-Calculus or Calculus AB in high school, as shown in Figure 2 below. Although a small percentage, some had even completed Calculus BC in high school. Considering the fact that these are students in an engineering program, this is no surprise. Among those enrolled in our program 87.5% had completed Pre-Calculus, Calculus AB or BC in high school – with 35.1% completing Pre-Calculus, 43.7% completing Calculus AB and 8.7% completing Calculus BC. One could reasonably expect that the percentage of students taking Calculus I, II and III as their first math course in college would have closely corresponding percentages. For example, those completing Pre-Calculus in high school would be expected to begin with Calculus I in college. However, the corresponding percentages of the first college math course are much lower with 25.6% beginning in Calculus I and a much sharper drop in Calculus II with only 17.5% taking this as their first college math course. Among the 52.4% enrolled in Calculus I, II, or III as their first math course in our

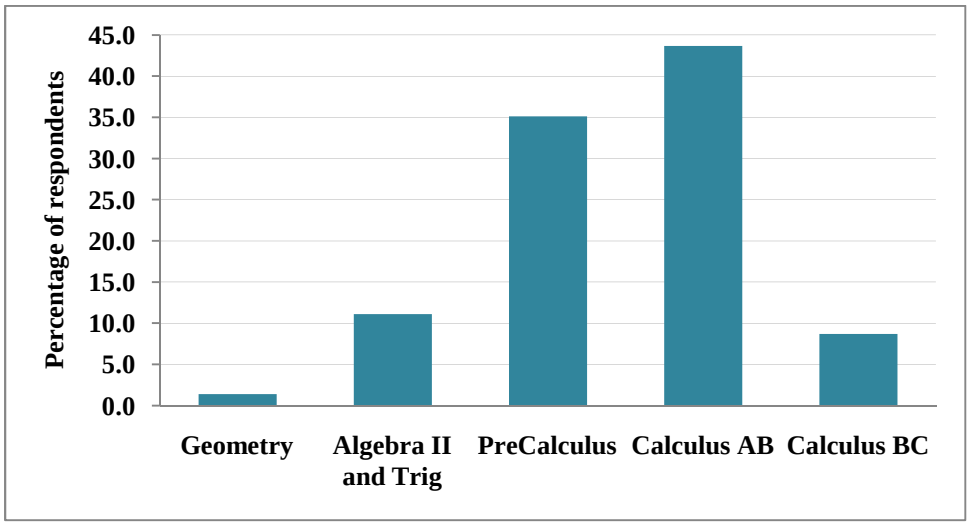

Figure 2: Last Math course completed in High School

college, there is a large group of transfer students who have taken one or more math courses at a different college campus. What catches one's attention is the fact that if such a high percentage of students (78.8%, as per Figure 2 below) are entering college with Pre-Calculus or Calculus AB already completed, then why so many students (47.7%) are beginning college below Math 2640 Calculus I level as shown in Figure 3 below.

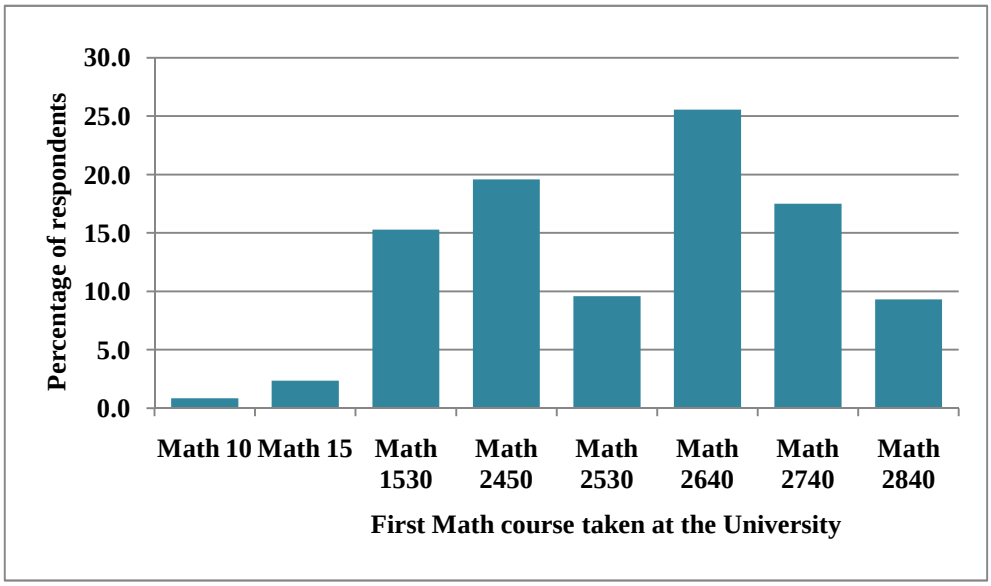

Figure 3: First Math course taken at the University

There could be several possible reasons for this. First, our students are not retaining math concepts learned in high school; secondly, they did not learn the concepts properly or adequately to begin with and finally, they did not take the college math placement test seriously. Another point of interest is the high percentage of students who say they have taken either Calculus AB or Calculus BC in high school (52.4%) but only 17% report an AP grade. This suggests that a large number of students take an AP math class in high school but quite possibly do not take the AP exam toward the end of the school year.

Any of these scenarios would also explain the large number of students receiving Math Placement Level (MPL) score of 20 or 30 in spite of the high percentage of the same group of students having completed Pre-Calculus or Calculus AB in high school. Faculty have held the assumption that because our state requirement for high school graduation is completion of only two years of math, we are getting more and more students who have not taken a math course since their sophomore year in high school or during their last year in high school. This study suggests that this assumption is not a valid one. About 81% of students taking the survey had taken a math course even during their last semester in high school. Therefore, the time lag between the last time they took a math course and taking the math placement test is not a factor in their performance on the placement test. With the exception of a few transfer and international students, almost all freshmen take their placement tests by freshman registration time in June and July every year within at most a month after high school graduation.

Many of the students surveyed did not respond to the question asking them to report their Math Placement Level (MPL) score. Several could not recall the scores suggesting that many students do not take these tests seriously. Over the years, faculty advisers routinely received similar comments from students during freshman registration sessions. With a ratio of almost 2:1, students expressed satisfaction with their placement scores. However, upon closely looking at individual responses and reading comments, it was observed that many were satisfied because they had taken Calculus AB in high school and were placed in Calculus I in their first semester in college. This was essentially a repeat and, therefore, other than the faster pace, they did not have much difficulty in their first math course in college. Many expressed satisfaction just because they had been placed in a calculus class. Not surprisingly, those who were not satisfied with their MPL scores were also those who had completed at least Calculus AB in high school but had placed lower for their first math course in college. Of those who reported – the highest percentage (37%) is an MPL of 40, which is the highest placement score allowing a student to be placed in Calculus I (Math 2640) or Calculus II (Math 2740). For Calculus III (Math 2840), Math 2740 is a prerequisite. A student with an MPL of 20 is placed in Pre-Calculus (Math 2450) and an MPL of 30 is placed in Trigonometry and Analytic Geometry (Math 2530). The MPL scores are discrete scores of 00, 10, 15, 20, 30 and 40. The placement options along with course number and title for the math courses are shown in Table 1 in the Appendix.

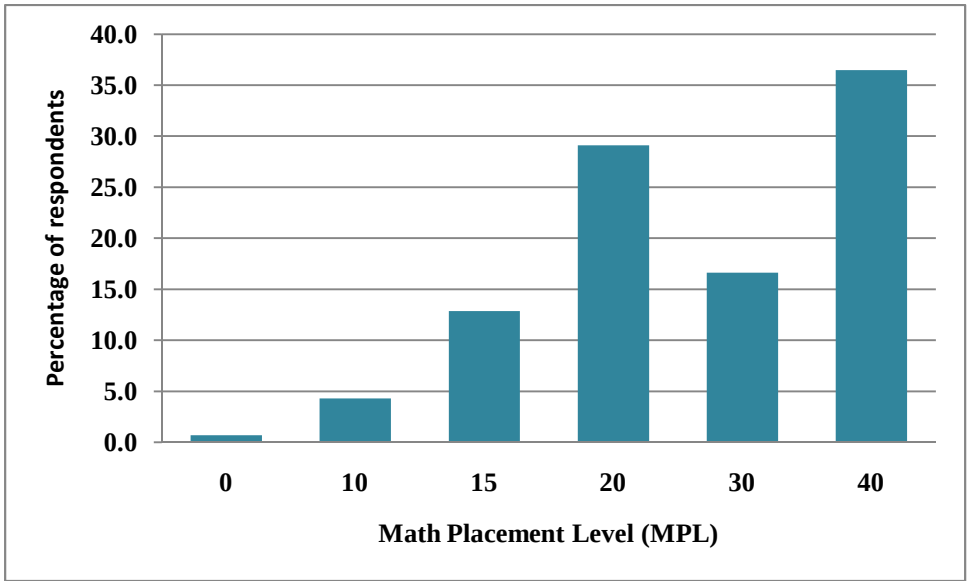

Figure 4: Math placement level (MPL) reported by students

Of the 719 respondents, about 72% reported to have scored between 20 and 29 on the math section of the ACT test with about 47% scoring in the range 25-29. This is within the expected range for our program. Students entering GE at this university must have an ACT math score of at least 22. Those who do not meet this requirement are placed in a pre-engineering program until they complete Calculus I with a grade of C or higher. As can be seen in Figure 5 below, roughly a quarter of the students surveyed report having scored in the range 30-36 in the math section of ACT.

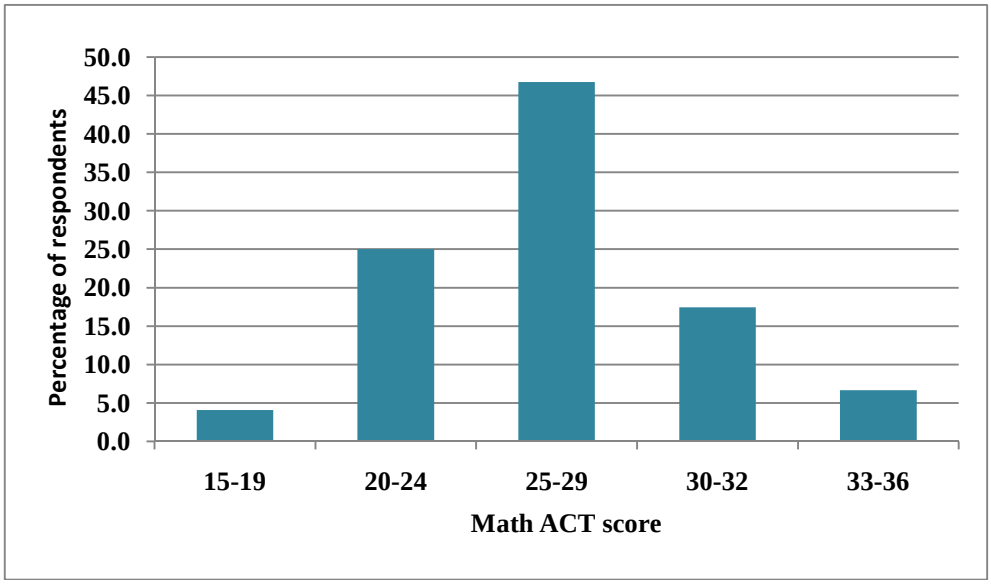

Figure 5: Math ACT score reported by students

An overwhelming majority of the students felt that they were adequately prepared (81.3%) for the first college math course, and on a scale of 1-10 they rated their math skills between 7 and 10. They probably had reason to be confident since 82.5% had received a grade of either an A or a B in their last high school math course, as they had reported. Yet, roughly a third of the students surveyed reported that they had to repeat a math course in college. Calculus I and Calculus II were the two courses that were repeated most often with 31.4% of students reporting that they had repeated Calculus I and 36.2% had repeated Calculus II.

Perhaps a sampling of the responses to the survey question, "What was the biggest challenge in the first math course that you enrolled in at the university" would help explain the situation:

"The pace at first and having to study."

"….getting used to tests and the way the professor taught the class. Remembering the concepts from Pre-Calculus was challenging."

"How you have to explain your answer sometimes – how you have to write really nice"

"…studying for the brutal tests and pop quizzes".

"Keeping up with home work – so many distractions."

"…transition from high school to college, learning new ways of studying".

The survey asked students to choose from a list of possible reasons or check "other" and explain if they were experiencing difficulty in the math course they were currently enrolled in. The reason cited more frequently than others (27.6%), was that exams were difficult. 19.6% reported that they were not studying enough. 15.3% had difficulty understanding the concepts in the course. 11.4% thought the pace of the class was too fast. Rounding up the top five reasons at 9.1% had too many classes on their schedule. Other reasons were: 8.4 % did not understand their instructor and 3% missed classes and exams. About 5% reported "other" and while some explained it, some did not – there was nothing consistent in this category.

Students were asked to report which GE courses they had completed or were currently enrolled in. This covered a span of ten courses offered in the GE Department. For each course they had completed or were enrolled in, students were asked to rate their math preparedness on a scale of 1-10 (10 being the highest) for that course. They were asked to explain what corrective steps they had taken if they felt that their math preparedness was rated below 5. Not surprisingly, none reported their rating below 5.

Students were asked about their biggest challenge in the GE class/es they had taken or were currently taking. Those that responded to this question mostly mentioned the difficulty of grasping the material, the amount of homework, relating equations and concepts to the problems and the fast pace in courses such as Statics, Dynamics, Mechanics of Material, and

Thermodynamics or learning and adjusting to the software in courses such as Graphics and Engineering Modeling.

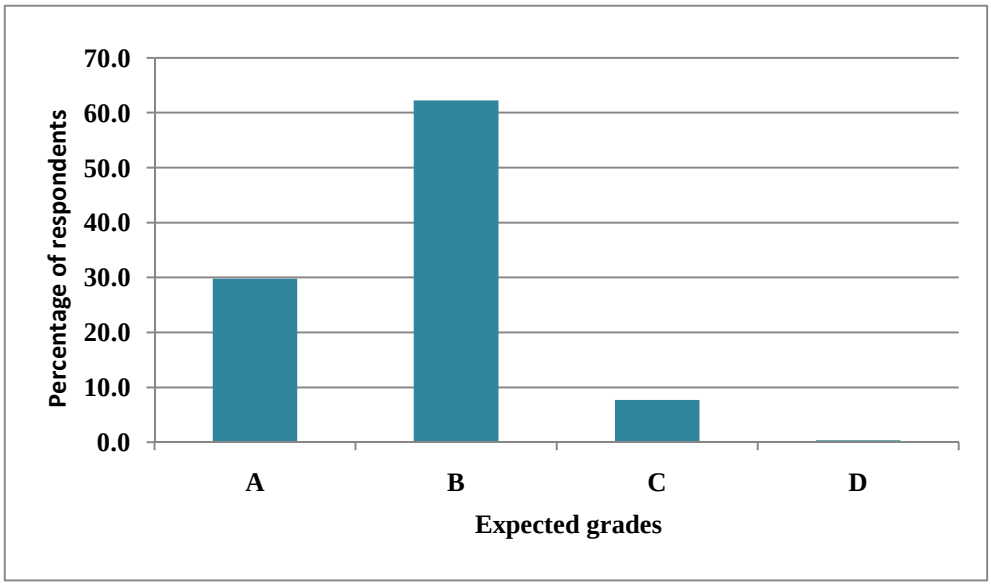

Figure 6: Students' perception of their performance in GE courses

Students' perception of how well they were doing or had done in their GE courses are shown in Figure 6 above. As can be seen from the graph, the majority of students seemed to think that they were receiving either an A or a B grade in their GE course. But in reality, that is not the case. Typically, in most GE courses, there is quite a spread among grades A-F. Although there are exceptions, many GE courses end up with about a quarter to a third of the class receiving an A and a similar number of students receiving B's and C's with a handful of D's and almost always, F's also. After close examination of final grades in randomly chosen eight sections of Engineering Success Skills (GE 1000), eight sections of Statics (GE 2130) and six sections of Mechanics of Materials (GE 2340), it was noted that 88% of the class had passed GE 1000 with a grade of A, B, or C, 93% had passed GE 2130 and 89% had passed 2340 with similar grades. What could not be taken into account was the number of students who had dropped these courses or were repeating the courses. It would be every instructor's dream to be able to teach their course in a way so that all students would pass their course with an A or a B. But at least at our university, we are far from achieving that dream.

Students were asked to rate on a scale of 1-10 (10 being the highest), how much they thought their math preparedness/competency had helped them in their GE courses. About 67% of the students responded with a rating of 7 or higher. The distributions of responses are shown in Figure 7. The individual comments showed that the introductory level courses such as Engineering Success Skills or Introduction to Engineering Projects were courses where they thought they didn't need a high level of math competency.

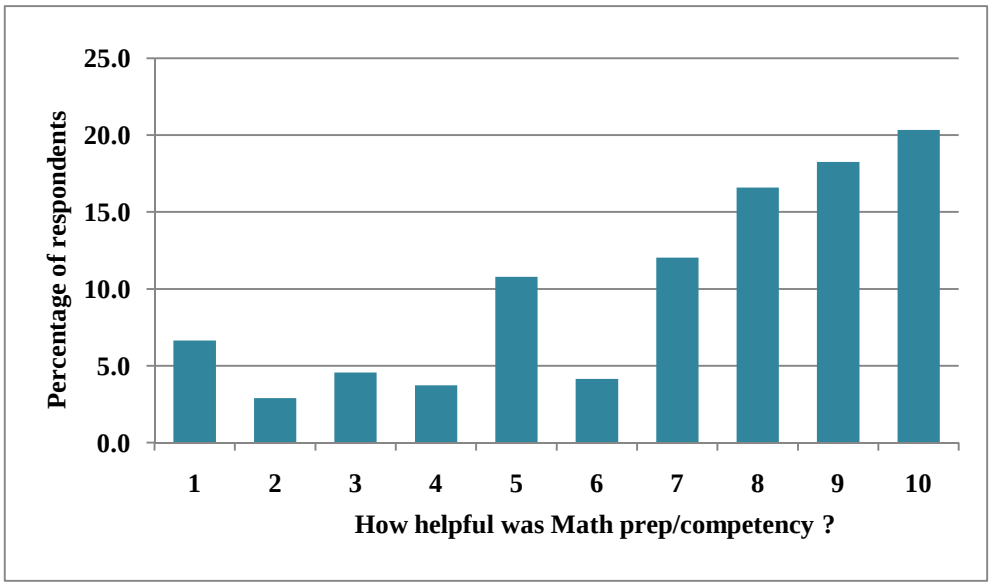

Figure 7: Students' perception of how helpful Math preparedness/competency was in GE courses

Finally, students were asked about their opinion on what could be done differently in high school and in college to help strengthen their math experience/preparedness. The majority of respondents thought that high-school math was more slow-paced and teachers took more time explaining concepts. For many, homework was never graded in high school and that called for an adjustment in college. Many wished high school math classes would be more like college math classes so they would have some idea in high school about what it might be like in college.

Conclusion

Several conclusions were made from the study. They are presented as follows:

A good majority of students in the program are not entering college with adequate math competency. Although more than half have completed Calculus AB or BC in high school - a significant number of students are retaking these courses in college and having to repeat them too.

About a third of the students surveyed reported that they had to repeat one or more math course at least once. The highest repeats were in Calculus I (Math 2640) and Calculus II (Math 2740).

When the combination of data on the first math course taken and math course completed prior to entering college is considered, the question of proper retention of concepts becomes significant.

Close to half of our students started below Calculus I which is bound to result in their taking longer to graduate. 1 in 5 students at our college begin with a low math placement and cannot enroll in an engineering or natural science course because they do not meet math pre- or co-

requisite requirements. They end up having to fill their schedules with classes that may meet the general education requirement or they may consider a minor outside the college while they wait two or even three additional semesters. This ultimately results in delayed graduation – much longer than the five year national average for a typical engineering undergraduate.

A large number of students do not take the math placement test seriously and do not understand the impact of a low math placement until much later.

Self perception of the students' ability and preparedness for the next level of math classes and engineering science courses are extremely high although the data indicates to the contrary.

The assumption that our state requirement of only two years of math for high school graduation is the reason we are getting more and more students who have not taken a math course since their sophomore year or during their last year in high school is not valid.

We as faculty and advisors need to do a better job of helping prospective students set their goals by explaining the entire curriculum and expectations, especially the first two years when they are required to take math, science and foundation courses in engineering. Simple strategies could be suggested to those that are admitted but are behind in math to minimize graduation delay, such as taking a math class over the summer before starting college.

In-depth look at high school math and science curricula and providing possible opportunities at the post-secondary level to facilitate a smooth transition into the engineering curriculum needs to be considered.

References

[1] B. J. Reys, S. Dingman, N. Nevels, D. Teucher, "High School Mathematics: State-Level Curriculum Standards and Graduation Requirements", Center for the Study of Mathematics Curriculm – An NSF Center for Learning and Teaching, http://mathcurriculumcenter.org

Appendix

Table 1: Mathematics course options based on Math Placement Level (MPL)

MPL	Course Number	Mathematics Course Options at the University
00	0010	Elementary Algebra
10	0015	Intermediate Algebra
15	1030	Mathematics for Educators I (for Education majors only)
	1530	College Algebra
	1630	Finite Mathematics with Applications

	1730 1830	Mathematics of Finance Elementary Statistics
20	2450	Precalculus
30	2530 2630	Trigonometry and Analytic Geometry Calculus with Applications
40	2640	Calculus and Analytic Geometry I