

A Math Review's Impact on Freshman Engineering Retention and Success

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Abstract - Many students enter engineering programs with high levels of interest and excitement but change majors or leave early in the first two years. To assist the transition of students from high school to the rigor of college level engineering courses, The Citadel developed a math review program to retain more engineering students. Recent years had more enrollment than what was expected. The challenge was to provide appropriate levels of scaffolding and curriculum engagement to help students be successful and keep them in the program. During the past fall, the Math Review was offered and provided a two and a half week (10 sessions) review of Pre-Calculus designed to prepare students for the rigor of college freshman math courses. Faculty from the civil, electrical, and mechanical programs conducted one-hour math review sessions in the evenings during the first 10 days of classes. The sessions were designed to be active learning sessions where instructors worked example problems followed by students working problems on the board and discussed the solutions. Some goals of the program in addition to covering fundamental topics were to model and encourage good work habits early in the semester and provide resources where students could find help on their own. Implementation of the Math Review showed success in creating a sense of community among the engineering students and reducing both withdrawals from math courses and changes of major when compared to the same point the year before. Through these freshman engineering initiatives, students were able to see themselves as engineering students and understand the types of knowledge and abilities essential to succeed. The objectives of this paper are to explain these readiness initiatives, to assess the first year program results quantitatively and qualitatively through retention data and surveys, and to discuss the future potential of the program.

Index Terms – Math Review, Freshmen Engineering, Freshman Retention

INTRODUCTION

In Seymour and Hewitt's book, *Talking About Leaving* [1], a review of student accession, retention, graduation, and hiring data showed many trends that were present in the 1990's and still present today. Some of the issues include:

loss of 40 -50 percent of entering freshmen engineering students in the first year due to lack of high school preparation, loss of motivation based on poor performance in courses that were normally their strengths in high school (mathematics and sciences), poor teaching, and inadequate advising or mentoring.

The first two years of typical engineering curricula require courses that include sequences in calculus and science. Students who start at Pre-calculus have an additional half year of mathematics before they are ready to begin the Calculus sequence. Many students struggle with these courses, change majors or leave the institution before they take an upper level engineering course. In essence, they never really take any engineering courses, but are discouraged through the prerequisites from other departments and instructors with no affiliation with engineering.

As a new initiative for the fall of 2015, The Citadel School of Engineering developed a short Math Review session for engineering freshmen. At The Citadel and most college campuses, students are pulled in multiple directions to be involved outside the classroom setting. At The Citadel, the time constraints are exacerbated by the additional military requirements. The basis for the Math Review was developed around similar research by Cavalli, Stanlake and Tolbert at the University of North Dakota where they assessed math preparation, social influences and personal perceptions of math. They concluded that the lower the current math course, the lower a student's perceptions were of his or her mathematical abilities [2]. Prior to 2014 the only retention initiative in place at The Citadel was Supplemental Instruction (SI) sessions held each evening in targeted math, science, and engineering courses that receive a significant amount (50% or higher) of D, F, and Withdraw (DFW) final semester grades.

Entering freshmen STEM majors at The Citadel without AP math credit must take a Math Placement Exam (MPE) before enrolling in courses. The MPE is used as a filter to determine whether a student should be placed in Pre-calculus or Calculus 1. Students beginning their preparation for a degree in engineering at The Citadel must complete a series of math courses that include Calculus 1-3 and Differential Equations 1 for civil engineers and Differential Equations 1-2 for mechanical engineers. Even among those who declared engineering as their major, nearly 50% of students placed into the Pre-calculus math course. The results of the math placement test quickly

determine if a student will have to complete an extra semester of math. Additionally, under-prepared students will face many challenges completing the civil or mechanical engineering programs.

EVENING MATH REVIEW

The Citadel recently launched new initiatives to attract more engineering majors. The past year saw over 25% of the new freshmen class select one of the engineering majors. To assist in the transition of students from high school to the rigor of college level engineering courses, The Citadel’s School of Engineering developed a Math Review program to attract and retain more engineering students. Over the past two years, The Citadel saw over 25% of the incoming freshman class select the civil or mechanical engineering majors. The challenge was to make these students successful and keep as many of them in the program as possible. During the past year, the Math Review was offered and provided a two and a half week (10 sessions) review of Pre-Calculus designed to prepare and review students. An indirect benefit of the Math Review was the encouragement of good work habits early in the semester with daily work and learning where to find help. With many general education requirements in the curriculum, engineering students typically do not experience in depth engineering coursework during the freshman year. However, it has been reported that success in an engineering program was highly correlated to confidence in math, science, and computer skills, Veenstra et al. [3].

Faculty conducted one-hour math review sessions Monday through Thursday evenings for 10 sessions. All freshmen engineering majors take an Introduction to Engineering course, so classrooms were identified based on the sectioning of the course. The Introduction to Engineering course is specific to the major. The faculty member who taught the section was the lead instructor for the Math Review sessions. Instructors worked problems or had students work problems on the boards and discussed the solutions. Often when the session was over, students stayed in the rooms to continue working on actual math homework.

Efforts in the Math Review were reinforced in the classroom. In the Introduction to Engineering courses, students were encouraged to build a working relationship with other students in their major and meet the faculty. The evening Math Review was less formal than a regular class and allowed the students to see his / her instructor a little more often so the faculty member was not an unknown person. The faculty tried to reinforce computations the students were also doing in Math, Physics, and Chemistry, such as projectile motion and stoichiometry. The classroom work that occurred at the same time as the Math Review sessions was reinforcement of the same type of material covered in the Math Review, but with engineering context. Problems had physical meaning and were not simple number manipulation. The instructors wanted to reinforce ‘time on task’ and ‘learning by doing’ early in the semester. Early in the semester, very few courses have significant

homework and no major requirements are due. There is a freshman student observation after a few weeks of college that they can survive by doing very little. Some of that perception is a result of previous experience in high school, but the engineering programs do not want to reinforce or develop that idea here.

PRE-SURVEY DATA

A survey to assess the incoming student population of 161 students was administered after the first session of the math review. Data was collected to determine their study habits from high school, confidence in their math skills and knowledge, and their expected grade in their first college level math course. With very little engineering coursework in the curriculum during freshman year, the authors felt that the math sequence was a fundamental part of the engineering curriculum that would give insight to student preparation and expectations. Table 1 shows that more than 73% of the incoming students coming from high school spent three hours or less per week on math. Over 31% spent less than one hour per week outside of class working on math. Students coming directly from high school are not being prepared for the necessary time on task and the rigor of college level courses with the college expectation that students should spend two hours outside of class for every hour in class.

TABLE 1
HIGH SCHOOL MATH STUDY TIME PER WEEK OF INCOMING FRESHMAN ENGINEER

Hours per week in HS studying Math outside of Class	%
0	7.88
<1	23.15
1-3	42.86
4-6	19.70
7-10	4.93
>10	1.48

Using the standard Likert Scale Table 2 indicates an incoming freshman average of 3.67 in confidence of their preparation of college level math courses. Nearly two-thirds (63.35%) felt confident (agree and strongly agree) about their math abilities.

TABLE 2
CONFIDENCE IN MATH SKILLS / ABILITIES OF INCOMING FRESHMAN ENGINEER

I feel confident in my Math Skills and abilities as I enter my Freshman Year in Engineering	%
(1) Strongly Disagree	0.62
(2) Disagree	8.07
(3) Neutral	27.95
(4) Agree	50.31
(5) Strongly Agree	13.04

Figures 1 through 6 show what the students thought they would earn in their first college math course, Pre-

calculus and Calculus 1, respectively. Specifically, Figures 1, 2 and 3 respectively show mechanical, civil, and electrical engineering pre-calculus results. Figures 4, 5, and 6 respectively show mechanical, civil, and electrical engineering calculus 1 results. Blue indicates an A, red was a B, and green was a C. The top of each bar shows the number in each category. The horizontal axis (final grade) compares the students' expectations (colored column), clearly showing the reality of the rigor of college math courses. For instance on Figure 1 for Pre-calculus, for those with the final grade 'D', 4 of 38 students or 10% thought they would get an 'A'; 2 of 38 students thought they would get a 'B' in the Pre-calculus math course. Similarly for Calculus 1 on Figure 4, for those with a final grade of 'C', 4 of 47 or 8.5% thought they would get an 'A', and 2 of 47 or 4.26% thought they would earn a 'B'.

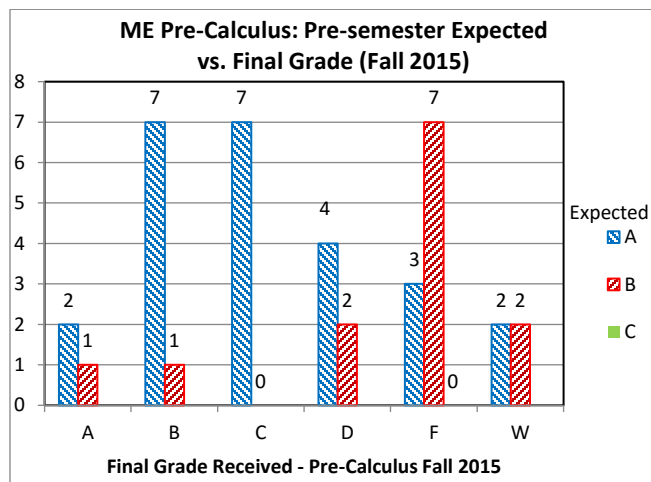


FIGURE 1
ME PRE-CALCULUS EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

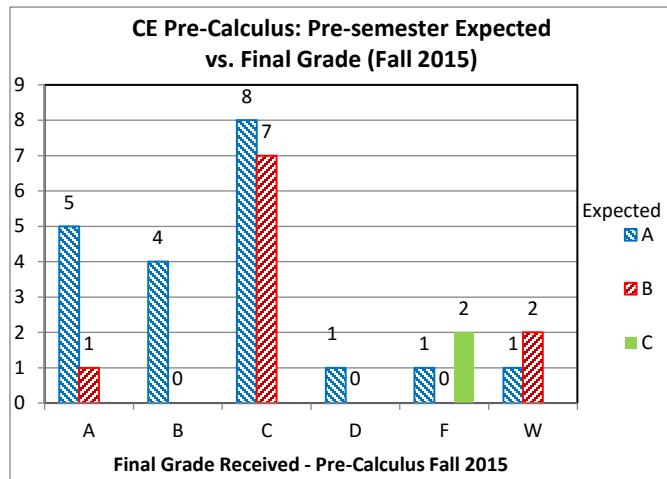


FIGURE 2
CE PRE-CALCULUS EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

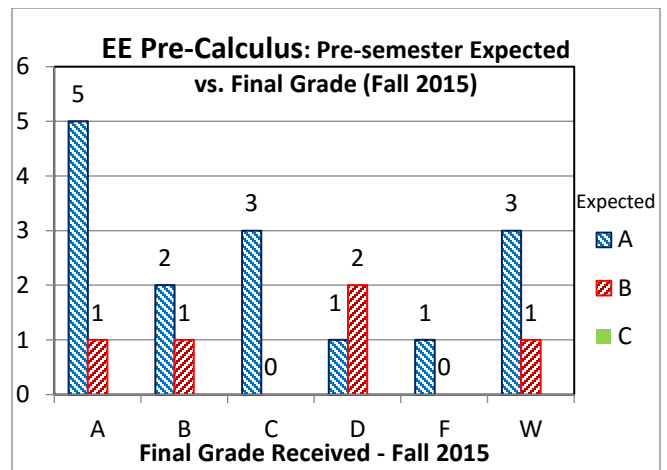


FIGURE 3
EE PRE-CALCULUS EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

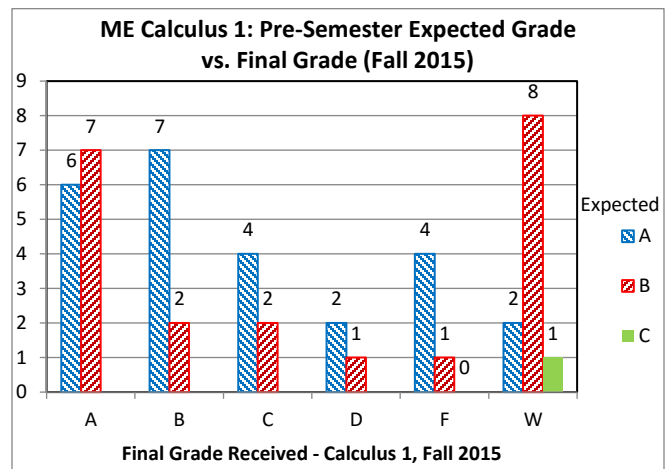


FIGURE 4
ME CALCULUS 1 EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

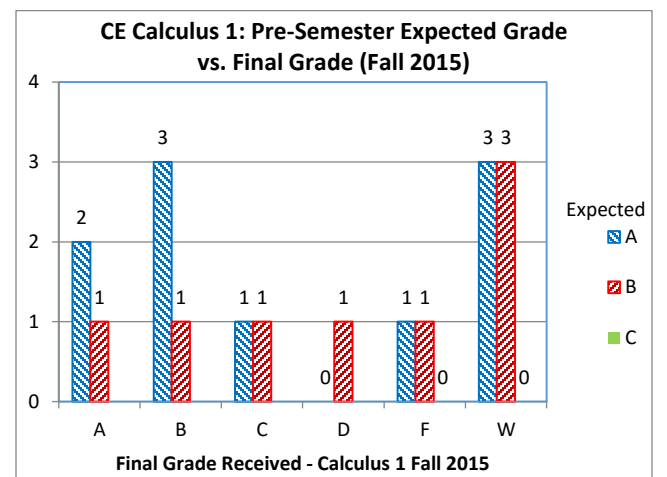


FIGURE 5
CE CALCULUS 1 EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

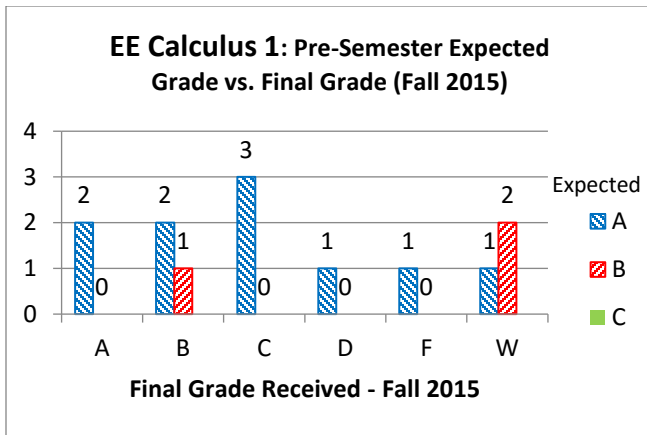


FIGURE 6
EE CALCULUS 1 EXPECTED GRADE (COLUMNS)
VS. FINAL GRADE (X-AXIS)

At mid-term, more than 58% were performing worse than what they predicted just two months earlier. For the final grades, 82 % performed worse than they predicted at the beginning of the semester. It is clear that many students entering from high school did not spend much time on math coursework, but felt very confident about their math skills. Their math scores for the semester show that only 18% met or exceeded their own expectation.

POST-SURVEY DATA

A student survey data was collected after the Math Review and focused on measuring students’ assessment of the Math Review. For the fall semester courses, the data from approximately 179 students was included in this study. Results from 55 CE students are in Figure 7, results from 103 ME students are in Figure 8, and results from 21 EE students are in Figure 9. The results are fairly positive, all above 3 points on a 5 point Likert scale from the first offering of the Math Review. Some limitations of the survey include limited information to other math reinforcement efforts conducted in math and science courses as well as variations among instructors in the Introduction to Engineering courses. Questions 1 and 2 are not displayed since they asked how many sessions students attended and what events / conflicts prevented the students from attending more. An additional analysis is being conducted to correlate the number of attended sessions and the final grades. For clarity, Table 3 lists the complete questions shown in the figures.

TABLE 3
POST SURVEY QUESTIONS

- Overall, the material covered in the Math Review adequately refreshed my skillset.
- I feel my math ability has improved since attending the Math Review Sessions.
- I felt comfortable asking questions or getting help during the Math Review Sessions.

- I plan to continue using academic support services (such as SI, Math Lab or STEM Lab) for the Math Course I’m currently taking this Fall 2015.
- My Math skills improved during this time due to the evening Math Review Sessions.
- My Math skills improved during this time due to my regular Math Course I am currently attending
- My Math skills improved during this time due to assistance from my classmates.
- I feel comfortable seeking assistance from different faculty in the School of Engineering.
- I would recommend the Math Review Sessions to freshman students next year.

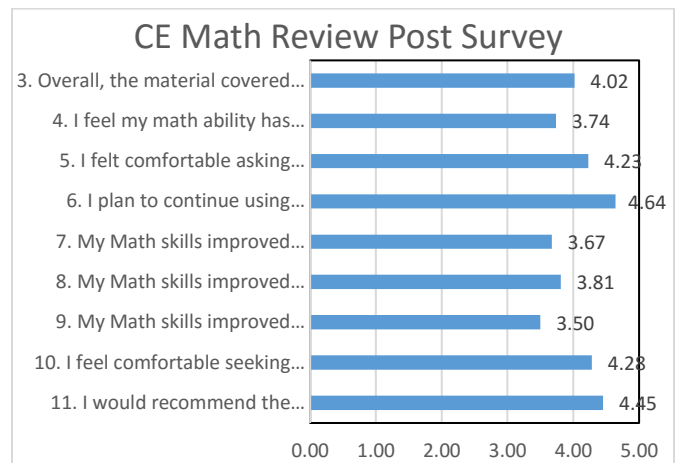


FIGURE 7
CE MATH REVIEW POST-SURVEY RESULTS

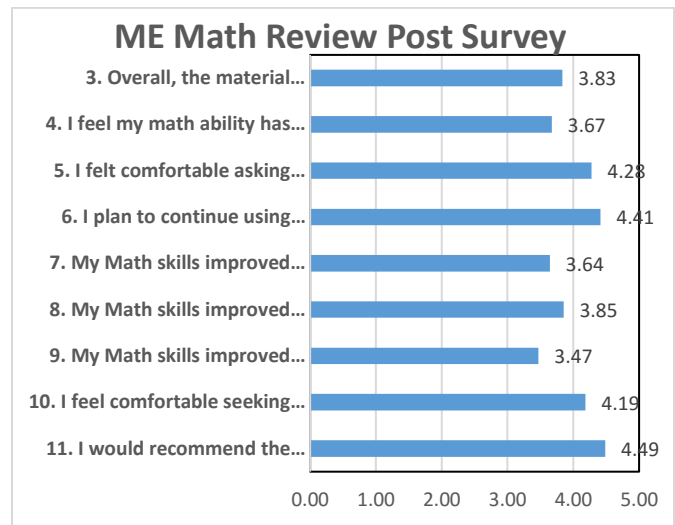


FIGURE 8
ME MATH REVIEW POST-SURVEY RESULTS

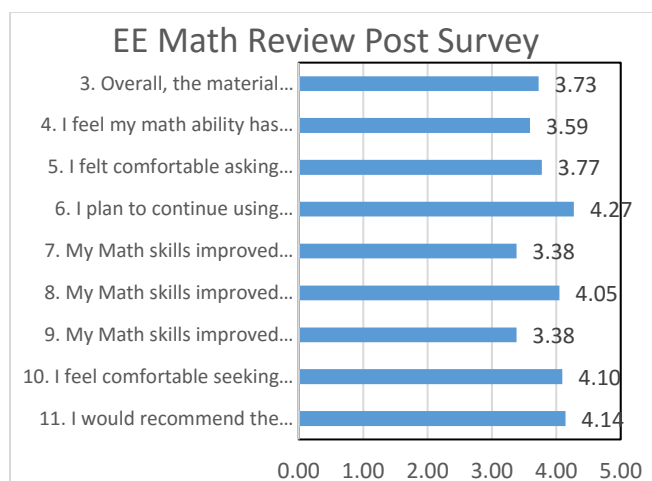


FIGURE 9
EE MATH REVIEW POST-SURVEY RESULTS

To evaluate the success of the Math Review in achieving another goal of increasing student awareness of tools, skills and resources needed to succeed in college, questions 5, 6, 9, and 10 inquired about external assistance. Question 9 was the lowest in all majors and the lowest overall. Given the fact that the students had only been on campus for three weeks and in classes for two, they did not feel overly comfortable seeking help from their peers. However, they felt comfortable asking for help during the sessions, using the academic support resources, and seeking assistance from the faculty. With a fairly small student population, many students have very similar schedules and often take many courses together during the same semester. Conditions are favorable for social integration to occur.

The highest rated question for ME (4.49) and the second highest for CE (4.45) and EE (4.14) was to recommend the Math Review sessions to students next year. Lower rated categories included the content of the Math Review sessions which was biased more to the Pre-Calculus students, although many were beginning Calculus 1. The students who had AP credit for higher math courses were peer tutors during the Math Reviews. Some who were registered for a higher level course found the material useful as a review for material not recently used in high school.

The Math Review’s informal instructional format of group study sessions created a relaxed and supportive learning environment. This created a sense of integration and connectedness that is evident in the results of participant responses to the post-program surveys.

DATA AND FINDINGS

To truly evaluate the success of the Math Review in helping students achieve their academic goals, the performance of the program participants was monitored to their final grade in their math course. Table 4 is a comparison of the performance of the students: ME Pre-Calculus, CE Pre-calculus, EE Pre-calculus, ME Calculus 1, CE Calculus 1

and EE Calculus 1. The performance measures compared are the retention rates.

The retention rate for the students with the Math Review showed some variation within the levels of the math courses: Pre-calculus retention rates were approximately 10% lower than Calculus 1 students. It appears that the students who arrived with higher math skills and abilities, have higher persistence to the rigor of freshman math. With many factors affecting student retention (changing majors vs. leaving the institution) and the limited length of this study, it is difficult to determine the true effect of the Math Review. However, the short duration of the Math Review (first 10 days of the semester) had a positive impact on developing a learning community and fostering good work habits early in the semester. The result is a reduction of the cost and time for some students to complete their degrees.

TABLE 4
COMPARISON OF 2015 MATH REVIEW STUDENTS

	# Fall	# Spring	Retention
2015 ME Freshmen Pre-Calc	39	29	74.4%
2015 CE Freshmen Pre-Calc	33	27	81.8%
2015 EE Freshmen Pre-Calc	21	16	76.2%
2015 ME Freshmen Calculus 1	47	42	89.4%
2015 CE Freshmen Calculus 1	18	16	88.9%
2015 EE Freshmen Calculus 1	9	8	88.9%
Total	167	138	82.6%

FUTURE WORK

As The Citadel’s Engineering programs attract a large number of entering freshmen, the faculty must monitor retention and ensure early experiences for the freshmen have a positive impact to retain them through graduation. Currently, the following programs or initiatives are expected to take place during the upcoming 2016-2017 academic year:

- Revised Math Review program during the initial weeks of the fall semester, conducted primarily during the day for consistency and to avoid evening extracurricular conflicts.
- Scheduled extra hour of math work session each week, conducted by the Math Department modeled after the School of Engineering’s initial Math Review.

In this present study, it is difficult to arrive at conclusions on how these review sessions affect freshman engineers in the long term. The faculty and staff will continue to monitor all data, and especially the freshman courses, to ensure they have a positive impact on the engineering freshmen as well as increasing numbers retained. It is probably not possible to design a Math Review that is perfect for every student. However, through continual assessment, feedback from students and efforts to improve student success, the authors believe these efforts can meet the student needs.

Overall, students enjoyed participating in the Math Review program. Many students approached facilitators after the sessions and shared their gratitude and ideas for future review sessions. The success of the Math Review program would not have been possible without the support of the Dean of Engineering and the Engineering Faculty that heavily promoted attending the events. This study will serve as a basis for continued growth in the outreach initiatives sponsored by the School of Engineering.

REFERENCES

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