

Effects of Readiness Initiatives on Mechanical Engineering Retention and Success

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Effects of a Math Readiness Initiative on Mechanical Engineering Retention and Success

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 and changed the science curriculum to attract and retain more engineering students. The Citadel recently launched a new mechanical engineering program that saw over 10% of the incoming freshman class select it as their major. During the second year over 15% of the new freshmen class selected the mechanical engineering major. Both years had more than twice the enrollment of what was expected. The challenge was to make these students successful and keep as many of them in the program as possible. During the second year, the Math Review was offered and provided a two and a half week (10 sessions) review of Pre-Calculus designed to prepare students for different freshman math courses. 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. Implementation of the Math Review showed success in creating a sense of community among the mechanical engineering students and reducing withdrawals from math courses or changes of major at the same point the year before. A similar math review with emphasis put on engineering quantities and units was administered during the first few classes in the freshman mechanical engineering 101 course. Student involvement was reinforced by assigning computational homework after each class. In freshmen mechanical engineering courses, the faculty reinforced material and computations the students were also seeing in Physics and Chemistry, such as projectile motion and stoichiometry. Through these freshman engineering initiatives, students were able to see themselves as a mechanical engineering student 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.

Introduction

The basis for the program was created with the student development theory of Tinto's Model of Student Retention in mind. Tinto's model is formed on the idea of integration, and he cited that student persistence is predicted by how involved students are in academic integration and social integration¹. At The Citadel and most college campuses, students are pulled in multiple directions to be involved outside the classroom setting.

The National Center for Education Statistics reported a total of 48 percent of bachelor's degree students who entered STEM fields during 2003-2009 had left those fields by spring 2009. Approximately one half of those students who left declared non-STEM majors, and the remaining left college prior to earning a degree². Many factors contribute to why students leave their STEM major including: college preparedness, less success in STEM courses versus non-STEM courses, type of institution (public or private) and dropping out of college.

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.

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.

Evening Math Review

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 1-2 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 have serious and adverse consequences for these students' timely completion of lower-division courses. It becomes quickly obvious that under-prepared students will face many challenges completing the mechanical engineering program.

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 15% of the incoming freshman class select the mechanical engineering major. 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. Veenstra et al. reported that success in an engineering program was highly correlated to "confidence in math and computer skills, actual math and science knowledge/skills, and career goals"³.

Faculty conducted one-hour math review sessions Monday through Thursday evenings for 10 sessions. All freshmen engineering majors take an Introduction to Mechanical Engineering course, so classrooms were identified based on the sectioning of the course. The faculty member who taught the section was the lead instructor for the Math Review sessions. When an instructor could not be present in the evening, another instructor was able to substitute in for the session. 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.

Classroom Reinforcement

The students were faced with topics in mechanical engineering about which they have no or some limited exposure in physics. In the Introduction to Mechanical Engineering course, students were encouraged to build a working relationship with other students in their major and meet the faculty. One aspect of this course that the faculty tried was to assign the instructor as faculty advisor for all the students in his/her particular section. There were some individual exceptions (two sophomores and one junior were assigned different advisors). This allowed the faculty member to inform advisees face to face for upcoming events and ensure advisees made appointments for advising before spring semester registration. At the same time, the students saw his / her advisor regularly, and this faculty member was not an unknown person.

The overall goals of the Introduction to Mechanical Engineering course were: 1) for students to learn about mechanical engineering as a career and introduce the different areas of mechanical engineering, and 2) to gain some knowledge and tools, which will help them as mechanical engineering students.

In order to accomplish goal 2 above, the faculty tried to reinforce computations the students were also doing in 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 merely number manipulation. The instructors wanted to reinforce 'time on task' and 'learning by doing' early in the semester. With few courses assigning homework and no major requirements in the first few weeks, there is a freshman student perception after a few weeks of college that they can survive by doing very little.

Chemistry for Engineers

The Grinter Report⁴ recommendations resulted in most engineering programs requiring at least one semester of freshman chemistry and many programs adding a second required course. In the 90s, Drexel University⁵ initiated an integrated curriculum which combined chemistry into larger modules with math and engineering content. Some programs created courses for specific majors such as "Chemistry for Engineers" courses⁶ while others were application-oriented, such as having an emphasis on materials⁷. In most studies of the role of chemistry in engineering education, the emphasis is on the chemistry content. The Chemistry for Engineers course and its effect on the mechanical engineer program will be covered in another paper.

Pre-Survey Data

A survey to assess the incoming student population of 104 students was administered after the first session of the math review. Data was collected to determine what math courses they had in high school and when, 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 instructors felt that the math sequence was a fundamental part of the engineering curriculum that would give insight to student

preparation and expectations. Figure 1 shows that more than 73% of the incoming students coming from high school spent three hours or less per week on math. Over 32% spent less than one hour per week outside of class working on math. With the college expectation that students should spend two hours outside of class for every hour in class, high school students are not being prepared for the necessary time on task and the rigor of college level courses.

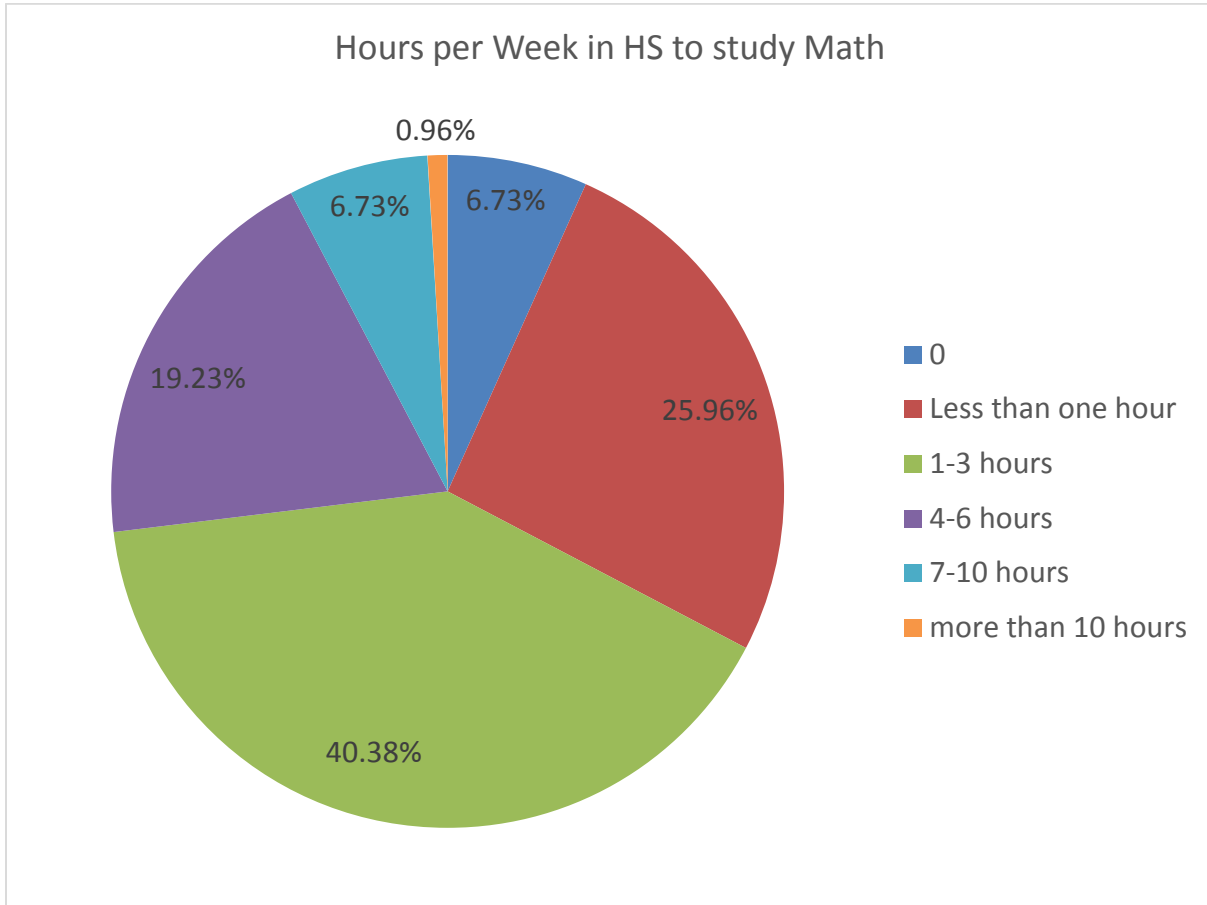


Figure 1: High School Math Study Time per Week of Incoming Freshman Mechanical Engineer

Using the standard Likert Scale (Table 1), Figure 2 indicates an incoming freshman average of 3.74 in confidence of their preparation of college level math courses. Over two-thirds (68.27%) felt confident (agree and strongly agree) about their math abilities.

Table 1: Assessment Scale

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

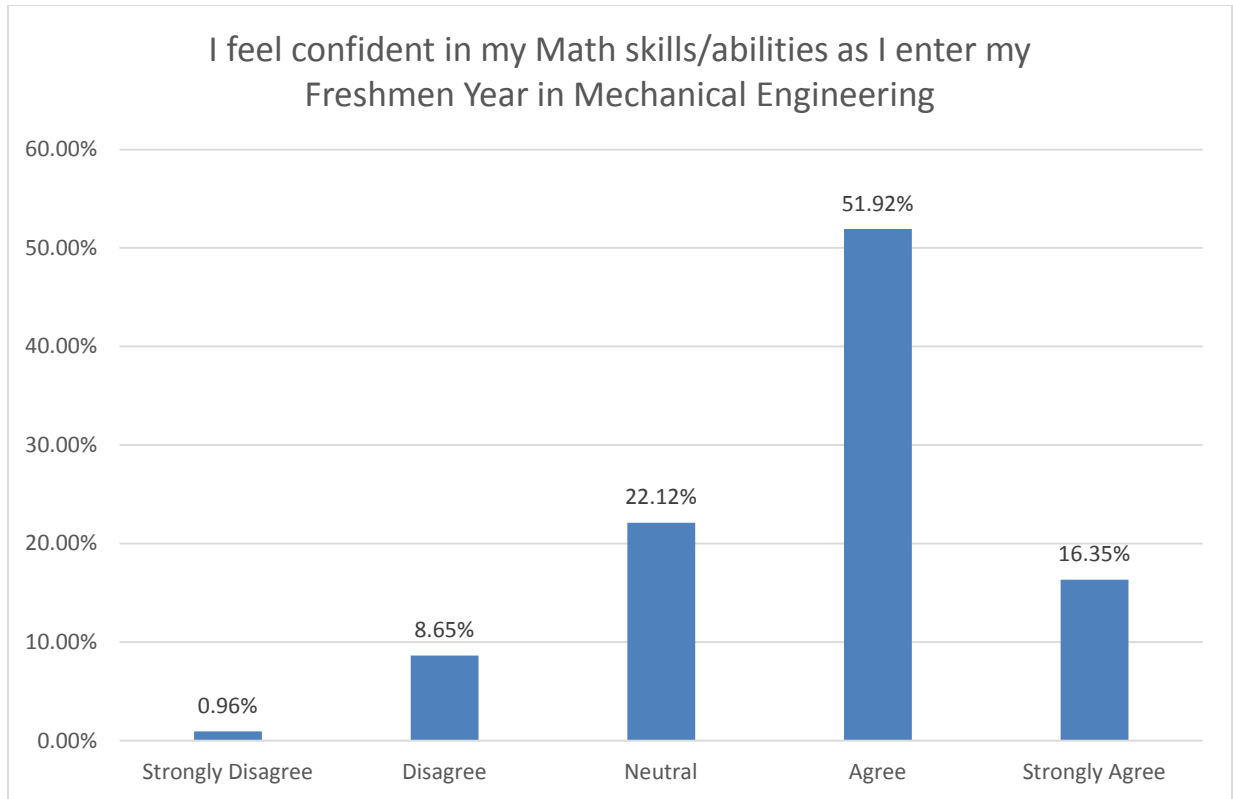


Figure 2: Incoming Mechanical Engineering Freshmen Math Confidence

Figures 3 and 4 show what the students thought they would earn in their first college math course, Pre-calculus and Calculus 1, respectively. 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 3 for Pre-calculus, for those with the final grade 'C', 7 of 38 students or 18% thought they would get an 'A' and no one 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'.

At mid-term, 61 of the 104 students surveyed or more than 58% were performing worse than what they predicted just two months earlier. For the final grades, 77 % were performing 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 22.5% met or exceeded their own expectation.

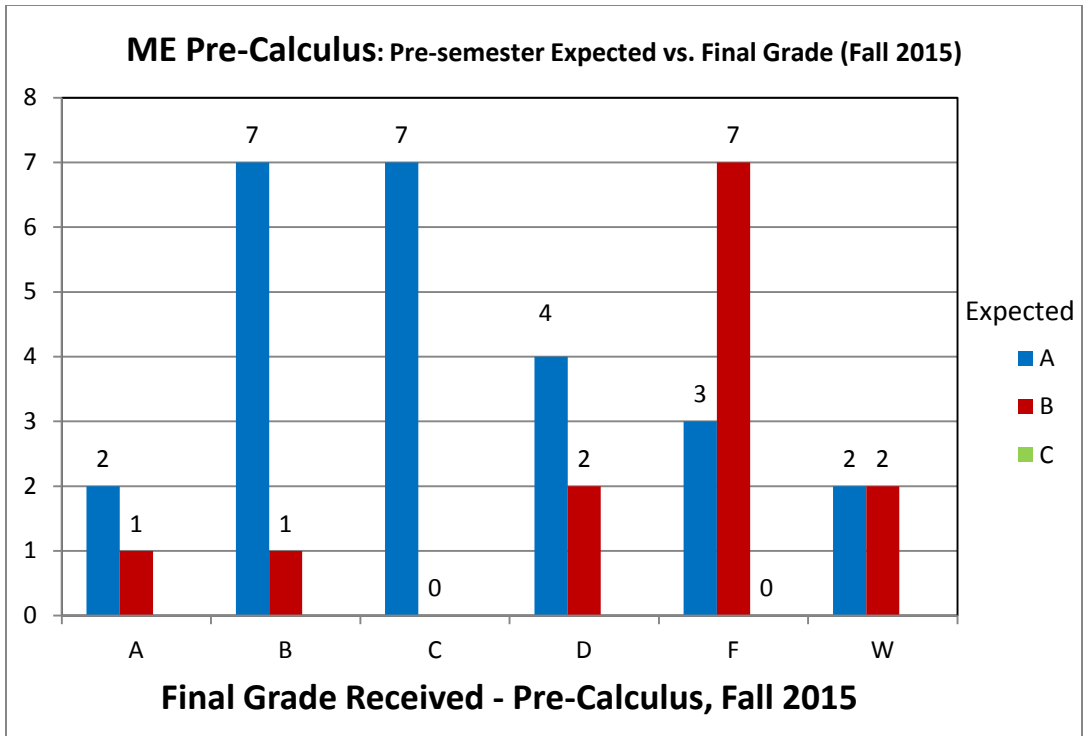


Figure 3: Pre-Calculus Expected Grade (columns) vs. Final Grade (x-axis)

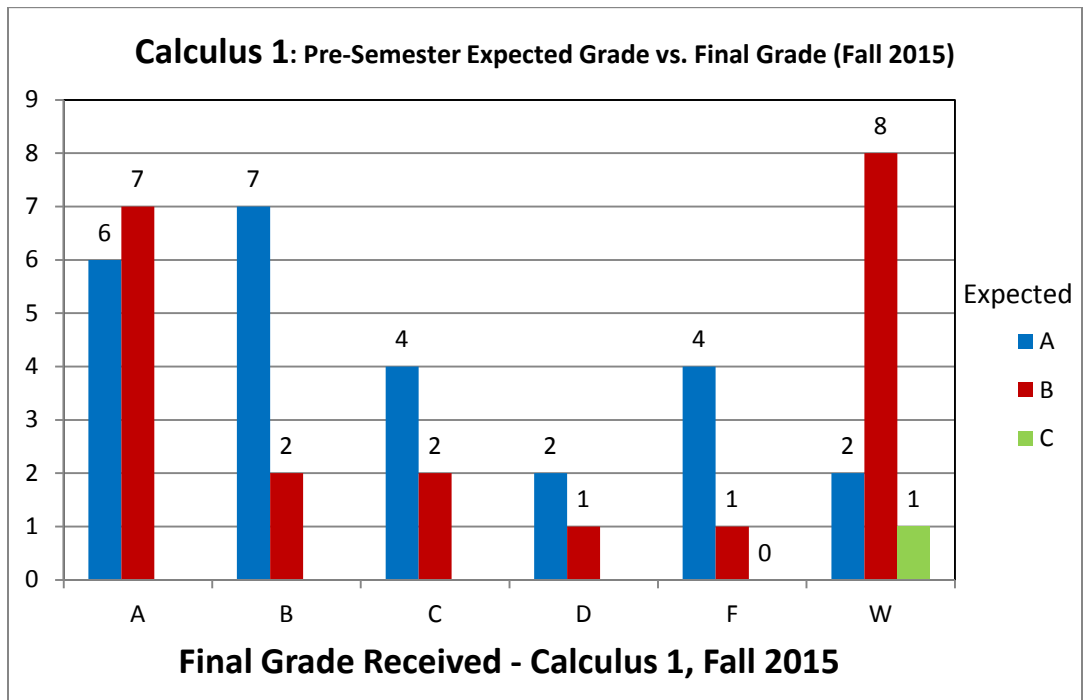


Figure 4: Calculus 1 Expected Grade (columns) vs. Final Grade (x-axis)

Post-Survey Data

The student survey data was collected after the Math Review and focused on measuring students' assessment of the Math Review (Appendix A). For the fall semester course, the data from approximately 95 students was included in this study. The survey shows the results from a first offering of the Math Review. The results are fairly positive, all above 3 points on a 5 point Likert scale (Figure 5). Some limitations of the survey include limited information to other math reinforcement conducted in math and science courses as well as variations among instructors in the Introduction to Mechanical Engineering course. 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.

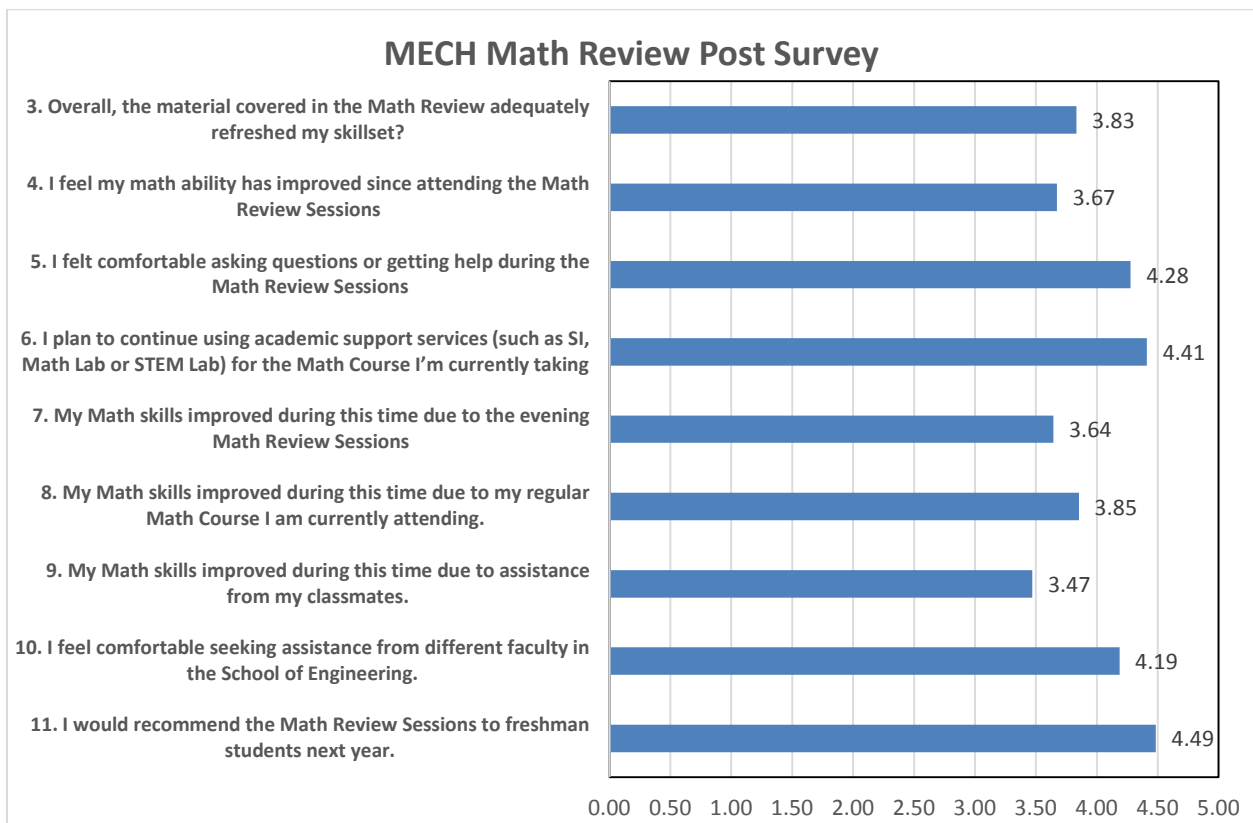


Figure 5: MECH Math Review Post-Survey Results

To evaluate the success of the Math Review in achieving its secondary goals 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 this area 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. To enhance opportunities for the creation of academic and

social integration, an approach that is of increasing popularity in colleges is the use of learning communities. Learning communities are groups of students taking several classes together that enhance academic and social integration of students, and strengthen their cognitive skills⁸. With a fairly small student population, many students have very similar schedules and often take many courses together during the same semester.

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 or 2. The students who had AP credit for these 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. It is interesting to note that overall, the highest rated question, 4.49, was to recommend the Math Review sessions to students next year.

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.

Free text replies reinforced the favorable hand-on nature of solving problems. Some comments are provided:

- Having someone break the math problems down further for a better understanding of how it works.
- Constantly having people there to encourage and help us out.
- Covering the basics, ensuring everyone is up to date and being able to help my classmates.

When asked what they found most helpful with the Math Review, typical responses included:

- Just working on problems is always helpful, especially if you are with a group that can help you if you get stuck.
- It helped refresh me on my pre-calc basis since I took that class in the 11th grade and am now taking Calculus I.
- The engineer community was there and I could get help on any question whenever.

While some aspects of the class were successful, the instructors received some feedback and are considering some revisions to the Math Review. One criticism was with the overall effectiveness of the review for some students. Some students already were quite advanced in their math, and much of the math review was repetition. Some students already had some college classes, and math review sessions aimed at student success were not useful to them. When asked what they like least about this course, some free text responses are listed:

- I already knew most of the material.
- Scheduling issues and only having one shot at each topic.
- The fact that I couldn't regularly attend because of other activities.

There were several time conflicts with the scheduling of the Math Review sessions, such as athletes being released from practice and dinner in time to attend the sessions, and other clubs, organizations, and religious activities occurring on the same evenings.

Correlation between performance in the freshman math courses and attendance at the Math Review was quite strong. While correlation does not necessarily imply a cause-effect relationship, the authors believe that the applied quantitative nature of the material in the Math Review, along with an emphasis on problem solving in classes, is very useful in developing the skills needed for success in engineering course work.

Data and Findings

To truly evaluate the success of the Math Review in helping students achieve their academic goals, the success of the program participants beyond the initial review period was monitored. To this end, the performance of the Math Review students in their math courses they took in fall 2015 was examined. Table 2 is a comparison of the performance of two groups of students: 2014 students who did not have the Math Review and 2015 Math Review students. The performance measures compared are the retention rate and success rates in the math courses.

The retention rate for the students with the Math Review showed a slight decline of 4%. With many factors affecting student retention (changing majors vs. leaving the institution) and the small difference from the previous year, no conclusions can be immediately drawn from the effect of the Math Review. However, the average Math grade for mechanical engineering freshmen showed an increase of 0.177 for those with the Math Review. Although this is not a large difference, 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 2: Comparison of 2015 Math Review and 2014 non-Math Review Students

	2014 MECH Freshmen (No Math Review)	2015 MECH Freshmen (With Math Review)
# Fall	78	101
# Spring	65	80
Retention Rate	83%	79%
Math Grade (GPA)	2.035	2.212
GPA Fall	2.843	2.908

Future Work

As The Citadel's Mechanical Engineering program continues to 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, probably conducted during the day to avoid evening conflicts with athletics, club, and religious activities.
- The Math Department plans to institutionalize an extra hour work session each week due to the success of the Math Review.

The School of Engineering will continue to implement and improve the Math Review and contribute to the strengthening of academic skills for engineering students.

In this present study, it is difficult to arrive at conclusions on how these review sessions affect freshman mechanical engineers in the long term. The mechanical program will continue to monitor all data, and especially the freshman courses, to ensure they have a positive impact on the decisions and interests of mechanical engineering freshmen as well as increasing numbers retained. It is probably not possible to design a Math Review that is perfect for every student, especially the first Math Review for such a wide variety of incoming students. However, through continual assessment, feedback from students and efforts to revise the course structure, the authors believe these courses can be greatly improved to 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.

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Appendix A

The Citadel – School of Engineering Math Review – Post Student Questionnaire

Name: _____ CWID: _____

Please select your major below:

	Major:
	Civil Engineering
	Electrical Engineering
	Mechanical Engineering

Gender:

Male Female

Ethnicity:

Caucasian Hispanic/Latino
 African American Asian Other

1. How many Math Review Sessions did you attend?

0-2 3-5 5-7 8-9 All 10 sessions

2. If you attended < 5 sessions, what obstacles prevented you from attending more sessions?
List below:

3. Overall, the material covered in the Math Review adequately refreshed my skillset?

Strongly Disagree Disagree Neutral Agree Strongly Agree

4. I feel my math ability has improved since attending the Math Review Sessions...

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. I felt comfortable asking questions or getting help during the Math Review Sessions...

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. 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...

Strongly Disagree Disagree Neutral Agree Strongly Agree

7. My Math skills improved during this time due to the evening Math Review Sessions.

Strongly Disagree Disagree Neutral Agree Strongly Agree

8. My Math skills improved during this time due to my regular Math Course I am currently attending.

Strongly Disagree Disagree Neutral Agree Strongly Agree

9. My Math skills improved during this time due to assistance from my classmates. _____

Strongly Disagree Disagree Neutral Agree Strongly Agree

10. I feel comfortable seeking assistance from different faculty in the School of Engineering. _____

Strongly Disagree Disagree Neutral Agree Strongly Agree

11. I would recommend the Math Review Sessions to freshman students next year. _____

Strongly Disagree Disagree Neutral Agree Strongly Agree

12. What did you find most helpful about the Math Review Sessions? _____

13. What did you find least helpful about the Math Review Sessions? _____

14. Any other Comments or Suggestions regarding the Math Review sessions: _____

