

## **Math Problem Solving Sessions for Freshman Engineering Success**

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**Abstract** – To assist the transition of students from high school to the challenges of college level engineering courses, The Citadel developed a math review program to retain more engineering students. Students who initially selected one of the engineering majors were tempted to change majors early due to difficulties encountered in non-engineering courses such as math. Recent years had higher enrollments than what was expected in engineering. The challenge was to provide appropriate levels of support and curriculum engagement to help students be successful and retain them in the engineering programs. For the past two years, the School of Engineering conducted a variation of Math Review sessions at the pre-calculus level during the first few weeks of the fall term. Engineering faculty conducted one-hour math review sessions in the evenings. The sessions were designed to be active learning sessions where instructors worked example problems followed by students working problems on the board and discussing the solutions. With some documented success in grade improvement and retention rates in the math review conducted by engineering faculty, the Math Department created a math review program modeled after the School of Engineering's. Prior to the current school year, freshman math courses met four times weekly. The new Math Review scheduled a math work session each week for one hour in freshman math courses. Math instructors were free to use the extra hour meeting time to work problems or they include shorter problem solving sessions throughout the week. The objectives of this paper are to explain this initiative, to assess the first year program results quantitatively and qualitatively through grades, retention data and surveys, and to discuss the future potential of the program.

*Index Terms* – Math Preparation, Freshmen Engineering, Freshman Retention

## INTRODUCTION

Success in pursuing an engineering degree can rely on many external factors such as student capabilities, motivation for job opportunities, and cultural and economic differences. However, there are many documented processes to create a positive environment for engineering students [1]. This paper will focus on the challenge of student engagement in

college level math courses. In an effort to improve the students' deeper learning and grasp of the material being taught, problem solving sessions were introduced in the freshman math courses. A recent opportunity to re-design the courses allowed the opportunity to reinforce lecture material with example problems in an attempt to help students learn the material in greater depth.

In Seymour and Hewitt's book, *Talking About Leaving* [2], 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 without engineering affiliation.

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 [3]. 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 number of students selecting one of the engineering offerings has grown 46% over the past six years. The past two years saw over 25% of the new freshmen classes 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 prepare and retain more engineering students. The challenge was to make these students successful and keep as many of them in the program as possible. The school found that many first year engineering students struggled with studying college-level math courses due primarily to their lack of explicit experiences or connection of math to real-world, engineering examples.

In the fall of 2015, 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, Litzer et al. [4].

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 Introduction to Engineering 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 doing in Math, Physics, and Chemistry, such as projectile motion and stoichiometry. The Math Review sessions were a reinforcement of the material that was being taught in math that included an 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 while other courses do not have significant homework or major requirements 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. There were challenges to get all engineering students to the Evening Math Reviews. Some students are athletes who had practice and dinner that conflicted. There were occasional religious activities or club functions that prevented full attendance of the engineering students.

### **WEEKLY MATH PROBLEM SOLVING SESSIONS**

In 2016 the School of Engineering held fewer review sessions, only conducting three evening math review sessions to the incoming engineering freshmen. The Department of Mathematics saw the value of the evening problem solving sessions that were conducted in 2015. Freshman and sophomore math courses were already meeting four times per week, so the Department of Mathematics formalized an extra one hour problem solving session into the freshman math courses. In theory, the problem solving sessions were dedicated time to reinforce that week's math topics. Instructors could accomplish this in the extra one hour block (no lecture or new material presented) or in smaller sessions during each class meeting. The freshman math courses, Pre-calculus, Calculus I, and Calculus II were four credit and four contact hours weekly and became four credit and five contact hours. The additional contact hour was included in the faculty workload for scheduling and appropriate compensation when necessary.

### **WEEKLY FOUR (4) HOUR SURVEY DATA**

A survey was conducted to assess the freshman population of 114 engineering students at the end of their first year (2016). Data was collected to determine their study habits, confidence in their math skills and knowledge, and how their instructors used available class time. 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. For

clarity, Table 1 lists the complete questions shown in the figures.

TABLE 1  
SURVEY QUESTIONS

3. Class time prepared me to be successful in completing my homework.
4. Time provided me with the skills and knowledge to pass the course & advance to the next level.
5. My Math Professor used time to Lecture only.
6. My Math Professor used time to Lecture and demo Practice Problems.
7. I now understand how math relates to my Engineering coursework.

Questions 1 and 2 are not displayed since they identify the student by engineering major and what math course they were taking, respectively. An additional analysis is being conducted to correlate the additional time and student success in follow-on math courses.

Additional survey questions also determined what academic support services students were using. With administration's emphasis on student success and retention, the authors wanted to determine what services were being used, and if there were any compounding effects with the additional hour of math contact time.

Finally, the survey queried the amount of time students were spending on math courses outside of the classroom. Students must devote the necessary time on task for the rigor of college level courses. The college expectation that students should spend two hours outside of class for every hour in class is not an easy adjustment for many.

#### WEEKLY 5 HOUR SURVEY DATA

A student survey was administered to assess the effectiveness of the additional hour of math exposure at the end of the academic year for the current freshman population of 165 engineering students (2017). Similarly, this survey was to determine their study habits, confidence in their math skills and knowledge, and how their instructors used available class time. For the fall semester courses, results from students are in Figures 1-3. Overall, the student ratings for this pilot program were neutral to positive, all above 3 points on a 5 point Likert scale (1 = strongly disagree to 5 = strongly agree).

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 Math courses. There were several new math instructors in 2016 (first time, college level math instructors).

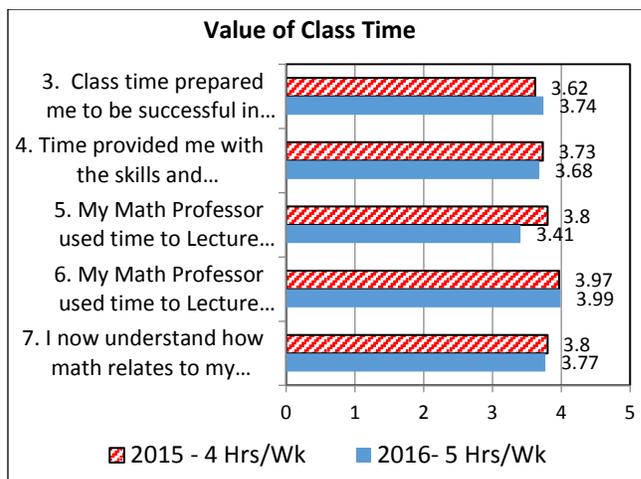


FIGURE 1  
CLASS TIME-SURVEY RESULTS

Some general positives (Figure 1) were observed in the following areas: student rating of confidence in math, and student perceived supportive relationships with tutors and faculty. The improvement in student perception of faculty lecturing only (Question 5) is statistically significant. Instructors who 'lectured only' decreased from 2015 to 2016 were the largest change in any of the questions.

The low level of change in Questions 3, 4, 6, and 7 (positive or negative) may indicate that the extra hour has no effect on students. These results point out that the shorter program may be as effective as, or even more effective than the semester-long, weekly engagement of problem solving. With the shorter two week program, students had more opportunity for early social integration with students in their engineering and math courses, creating opportunities for student engagement and immersion. Enriquez elaborated that this kind of experience also increases student persistence [5].

For Academic Support Services (Figure 2), students used the formalized tutors more during the 5 hour / week semester (2016). This could be a result of additional announcement of these services. However, the same students used both math and engineering professors significantly less than the 4 hour / week math students (2015). With the extra hour of instructor exposure, many students were receiving the extra help they needed. In 2015, freshmen saw their engineering professors as resources in both engineering and math. This can certainly contribute to the higher frequency of seeking math assistance outside of the classroom from an engineering professor. The survey does reveal that most students realize there is assistance available and are willing to seek help and not do it alone.

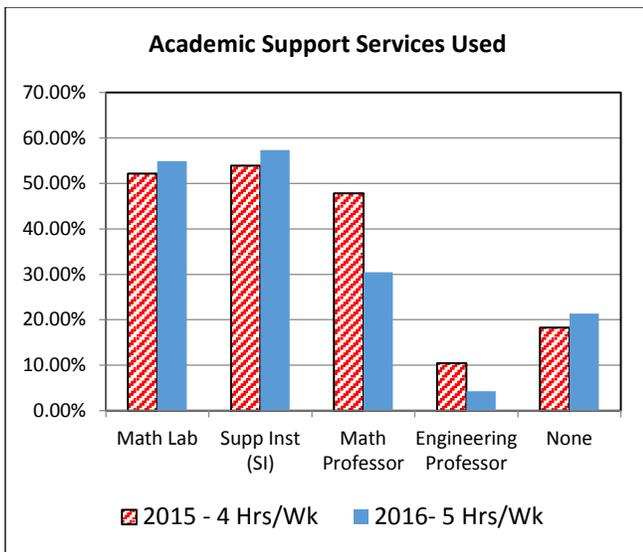


FIGURE 2  
ACADEMIC SUPPORT SERVICES USED

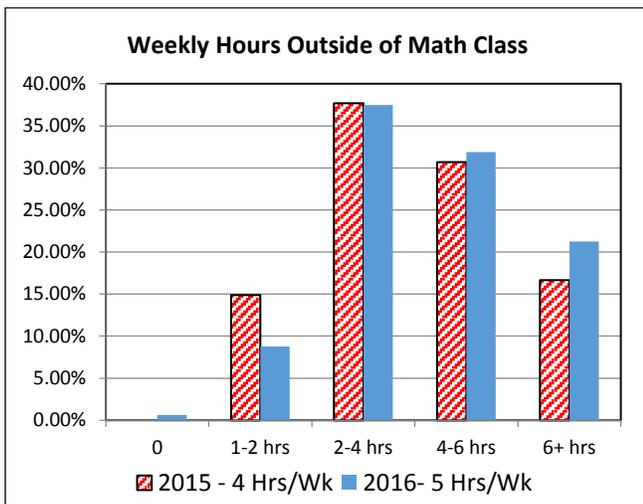


FIGURE 3  
WEEKLY MATH COURSE PREPARATION

Finally, the amount of time students spent outside of their math class each week preparing for math was low for both groups (Figure 3). The expectation is approximately 8 hours for a four credit hour course. The majority of students were spending approximately half that time. It can be argued that there was an additional hour of math practice during the hour long problem solving session, but this would only bring the total up to five hours, still much less than required for mastery of the topic. For demanding technical or abstract courses, Landis suggests that two hours of studying for every hour in class may not be enough. The appropriate number may be three or more [1]. It is not uncommon for freshman students to relate significant differences between high school and attending college for engineering. In high school most of the work is done in

class, so time management is prescribed for the student. There is a set class for math and most of the coursework is done in that class time. In college, instructors lecture, then they assign homework, and students often underestimate the time it takes to complete assignments.

#### 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 (Figure 4). The engineering curriculum begins with Calculus I, and it can be seen in the figure that students who had the five hours of math per week fared better than those who only had the four hours per week the previous year. The lower grades in the Pre-Calculus class did not follow this trend and can be attributed to a number of factors. These are the courses that many of the new, first time instructors were teaching, so their baseline of student motivations and knowledge were being established. Also, these were the students who selected one of the engineering majors but were not prepared for the first math course in the engineering sequence. Thus, they were not prepared for the college level math requirements from their high school experience.

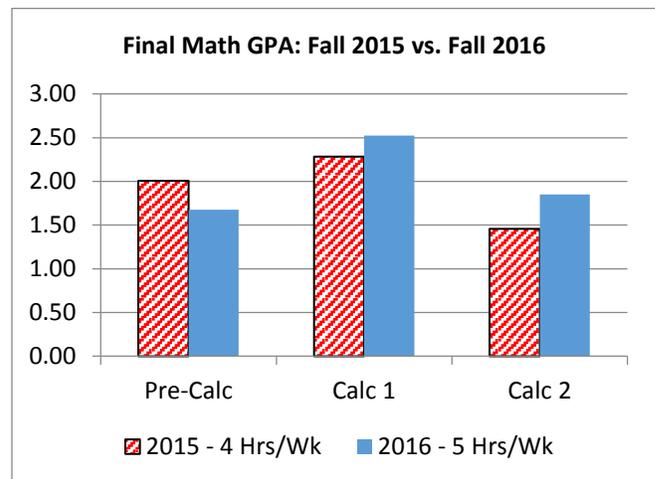


FIGURE 4  
FINAL GRADE RESULTS

One of the objectives of the Math Review Sessions and now the Math problem Solving Sessions is to reduce the number of D, F, and W (Withdraw) grades in the courses. Figure 5 shows the fall 2015 and 2016 DFW rates for all the freshman math courses. In all three courses, there is a clear decrease in the percentage of students receiving a D,F, or W. This is significant because Pre-Calculus and Calculus I have a minimum grade requirement of 'C' or better to advance to the next level of math. This helps retain more students in engineering and does not require students to make up courses over the summer in order to keep on schedule for graduation.

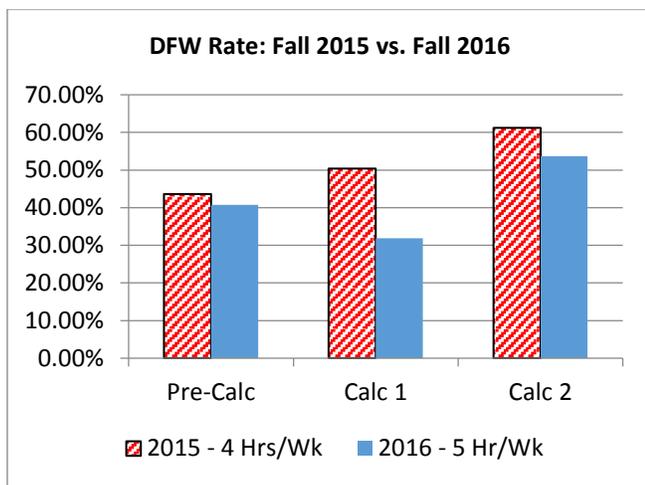


FIGURE 5  
DFW RESULTS

Although the results are generally positive, the improvement may not be a direct result of the 5 hour per week pilot program, since the DFW rates were also affected by other factors, including: new instructors and administration interest in this area.

Free text replies reinforced the favorable nature of the extra hour of math used as problem solving sessions. When asked what can be done to improve “how your math relates to engineering” experience, typical responses included:

- Make math problems relevant to ME [CE, EE] problems.
- Integrate the courses.
- Have a Math for Engineering class.
- Need a great way of getting student to recognize the correlation between math and engineering.
- When a lesson is taught, specifically mention what math it uses.

Some of the constructive feedback came from the question of what they liked least about the course:

- We do not need all 5 days.
- Curriculum needs to be adjusted or some GPA boost initiated.

Some students felt that the Math faculty were too harsh, which perhaps is not surprising considering the low overall GPAs. Again, many of the instructors in these three courses (7 of 14 sections) were first time faculty having no experience teaching and interacting with freshmen.

#### 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. A larger freshman population means more variability in student abilities and preparation for college level work in

general and engineering programs particularly. When students depart from engineering or the institution altogether, the attrition is harmful to the student, the engineering disciplines, and the School’s reputation. Everyone benefits by improving students’ chances of success.

The Math Review Sessions were designed primarily to help students who chose one of the engineering disciplines but have low levels of preparation for taking college-level math courses as indicated by their math placement test results. The success of the Math Review Sessions has prompted the Math Department to institutionalize a new program to add extra problem solving time for the students. The School of Engineering and the Department of Math will continue to implement and improve the math preparation to strengthen the STEM educational pipeline for students. Currently, the following programs or initiatives are expected to take place during the upcoming 2017-2018 academic year:

- Improving the existing in-class engineering related problems so students walk away with a usable example.
- Engineering professors (short, guest appearance) working an engineering problem using a current math topic

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