

AC 2009-1881: THE ENGINEERING-MATH COMMITTEE: A SUCCESSFUL COLLABORATION AT ____ UNIVERSITY

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The Engineering/Math Committee: A Successful Collaboration at East Carolina University

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Abstract

At most campuses in the United States with engineering programs, the engineering mathematics courses are taught by the mathematics department. Since many of these mathematics departments also teach Calculus, Differential Equations, and Statistics courses to students of all majors, it can be difficult to insure that the engineering students receive the specific course content they need. These generic mathematics courses often lack engineering examples that can help students understand how to later apply appropriate formulas in courses such as Statics, Dynamics, Circuits, and Strength of Materials.

At East Carolina University, we have established an Engineering/Math Committee. This committee is responsible for the development and implementation of specialized engineering sections of Calculus, Differential Equations and Linear Algebra, and Statistics. The committee has also made great strides to improve the placement, retention, and success of engineering students at East Carolina University. Efforts of the committee have led to the inclusion of both direct and indirect measures of assessment of the engineering courses being conducted by the mathematics faculty.

This paper discusses the work of the Engineering/Math Committee at East Carolina University. It details steps taken in curriculum development, mathematics placement, and student retention and success. Anecdotal feedback as well as statistical analyses of student performance is presented as a means to track improvement of our students' mathematical skills. It also suggests how to implement a successful Engineering/Math Committee and provides a summary of the benefits that have resulted from the work of this committee at East Carolina University.

Introduction

The Engineering Program at East Carolina University began in the fall of 2004. As a part of the initial curriculum, engineering students were required to take Calculus I (4 hours), Calculus II (4 hours), Statistics I (3 hours), and a course in Differential Equations and Linear Algebra (4 hours). All of these courses were taught by the Mathematics Department. Although a strong core of the initial class of engineering students performed well and continued with the program, the level of retention was below the expectations of the Engineering Department. Further investigation into students' reasons for leaving the program revealed that student retention had been impacted by lack of success in some of the mathematics courses. In an effort to increase retention and improve performance in mathematics courses, an Engineering/Math Committee (EMC) was established in the spring of 2007.

Forming a Committee

When it became known to the mathematics faculty that the existing math courses were not meeting the needs of the engineering students, they proposed designing courses that would be targeted specifically for these students. The engineering students were taking the first two courses in the traditional sequence of three calculus courses. This traditional sequence was taken primarily by mathematics majors, mathematics education majors who would go on to teach high school, and science majors in physics or bio-chemistry. It was recognized that the emphasis in these courses was more on theory than on applications, making them not optimal for the engineering students. Several years earlier the math department had designed a two-semester calculus sequence for biology majors that had proved successful and that was currently being taken by hundreds of biology majors per year. The two three-hour courses in this sequence emphasized calculus topics that the biology faculty considered important and included applications to the life sciences. The mathematics faculty felt that a similar tailoring of courses could be done for engineering students.

Members of the mathematics undergraduate committee met with a group of engineering faculty to talk about the possibility of designing a sequence of calculus courses specifically for engineering students. In the initial engineering curriculum, Precalculus was included¹. At the advice of an outside reviewer familiar with ABET standards, the curriculum was modified during the fall 2006 semester. Precalculus was removed from the engineering curriculum and Calculus III was added. Due to the number of required engineering credit hours in the curriculum and the number available for math and science credit, the engineering department requested that the courses in the new engineering calculus sequence be three credit hours each.

The faculty group decided that the first two courses should cover essentially the same material that was in the traditional four-credit Calculus I and II that the students had been taking, but with less of a theoretical focus. Applications would be emphasized, particularly applications related to engineering. Class material and homework assignments would be very carefully chosen to include as many engineering examples as possible and to accommodate for the reduction in credit hours. For the third calculus course in the new sequence, the traditional Calculus III course would be modified in a similar way. At the end of three semesters, students taking the new sequence would know essentially the same material as if they had taken the four-credit Calculus I-III sequence, but would have more awareness of how calculus could be applied to their course of study.

Since the Engineering program at East Carolina University was new, the upper administration was very interested in student retention and, as part of this, in improving student performance in mathematics. The Deans of the two colleges housing the math and engineering departments believed that maintaining the communication between the two departments was essential to bringing about this improvement. They established the Engineering/Math Committee (EMC) to formalize the interaction between the departments and to ensure that it would continue. The EMC would develop and oversee a mathematics curriculum that would enhance the engineering program and facilitate student retention.

The initial membership of the committee was a core of engineering faculty who were interested in recruiting and retention of good students, in developing a learning community to support these efforts, and in strengthening the core curriculum of the engineering program. The Engineering Department has a faculty member who serves as the department's Coordinator of Advising and Retention (CAR). The CAR was included on the EMC to bring focus to the committee's efforts to improve retention. The mathematics faculty included the instructors of the mathematics courses taken by the engineering students along with a member of the undergraduate curriculum committee. The Chairs of the Engineering and Mathematics departments were invited to attend the meetings of the committee as needed to discuss any relevant departmental issues but were not considered committee members. The committee decided to meet at least once a month during the academic year. Meeting agendas were set by an engineering faculty member, with invited input from all EMC members.

Committee Tasks

The EMC's functions centered on the two goals of developing a suitable mathematics curriculum and improving engineering student retention. The committee was charged with developing new courses as necessary, refining and maintaining all the mathematics courses taken by the engineering students, choosing textbooks and software appropriate for these courses, and placing the students in the correct courses. The committee also would oversee the assessment of these courses, ensuring that both formative and summative assessment were carried out and that data collection and data analysis occur as needed. The committee would provide input to department chairs about scheduling, making recommendations regarding the number of sections that should be offered, the times for these classes, and the instructors that should be considered to teach them. Additionally, the committee would develop mechanisms for tracking the engineering students in their math classes and for supporting the learning community by aiding in the selection and scheduling of tutors. These final two committee tasks would be aided by a line of communication that would be created between the math professors and the engineering Coordinator of Advising and Retention (CAR). This communication would allow the Engineering Department to track the effort (i.e., attendance) and performance (i.e., grades) of their students. Details on how many of these tasks have been and are being accomplished are provided in the following subsections.

Deciding on a math curriculum

Two of the committee's most difficult tasks were to decide what math courses the engineering students should take and then to design the courses that were not already in existence. Over the course of several meetings in the spring of 2007, it was decided that the students should take three courses in calculus (3 hours each), a course combining differential equations and linear algebra (4 hours), and one course in statistics (3 hours). Many of the faculty members that had originally met were now on the EMC and decided to pursue designing a new three course sequence of calculus classes to replace the traditional Calculus I and II classes that the engineering students were currently taking. The plan was for these new courses to emphasize engineering applications and to be three credit hours each instead of the previous four. There was an existing course in the math department in differential equations and linear algebra that the committee decided to use, but this course was renumbered as a fourth course in the new engineering calculus sequence. While many engineering programs do not require statistics, the engineering faculty felt strongly that it should be included in their program. The course taken by

the engineering students is similar to the one required of math majors, with some minor content modifications. All of the five math courses were to be taken in sections consisting only of engineering students to make tracking their progress simpler and to provide a narrower focus on engineering applications and examples. It was also thought the smaller sections consisting solely of engineering students would enhance the engineering students' sense of community.

Creating Syllabi for the Engineering Calculus Sequence

The faculty on the EMC first had several long meetings about what topics should be included or emphasized in a calculus sequence for engineers and what topics should receive a lighter treatment or be eliminated altogether. Preparing students for their later courses in engineering was a major consideration in these discussions as was student preparedness for the Fundamentals of Engineering (FE) exam. The faculty used both the FE review manual² and a sample/practice FE exam³ to guide their choices of material. Based on these discussions, the math faculty selected the following textbook that emphasized engineering applications: Calculus: Early Transcendental Functions, 3rd edition, by Robert Smith and Roland Minton, McGraw Hill Co. Inc., 2007.⁴

Another advantage of this book is that it could be partnered with the web-based homework program MathZone⁵. There were many benefits to adopting web-based homework: the examples on MathZone closely parallel those in the book and thus included many examples relevant to engineering, a student having difficulty completing the problems can view a similar example worked out in detail – so the program essentially functions as a tutorial, and the program enables the students to get instant feedback on the correctness of their answers. Using MathZone also allows for less time to be spent in class on homework and quizzes, making it more feasible to accommodate the reduction in credit hours (from four to three for each course) without a substantial reduction in content. The following paragraphs provide a summary of the modifications that were made in the traditional calculus sequence to obtain the syllabi for the new engineering calculus courses.

For Calculus I, the traditional sequence includes a short review of precalculus, limits and continuity, differentiation, applications of differentiation to curve sketching and word problems, and a brief introduction to integration including antiderivatives, the definite integral, and the Fundamental Theorem of Calculus. The new Engineering Calculus I includes all these topics and also transcendental functions. The treatment of the definition of limits, continuity, the definition of the derivative, and the definite integral are less rigorous and less in-depth than in the traditional Calculus I class. However, the Engineering Calculus class places more emphasis on numerical applications of the derivative such as linear approximations and Newton's method. Engineering applications are emphasized throughout the course and include using the derivative to analyze a spring mass system or a simple electrical circuit.

The traditional Calculus II course includes applications of the definite integral such as finding volumes of solids of revolution, integration techniques, an introduction to differential equations, transcendental functions, and series. The new Engineering Calculus II class includes all of these topics with the exception of transcendental functions, which is covered in the first course. But again, more applied topics and engineering applications are emphasized. These include methods of numerically approximating a definite integral such as the Midpoint Rule, Simpson's Rule, and

the Trapezoidal Rule. Integrals are also used to compute work, mass, centers of mass, and hydrostatic force.

The traditional Calculus III class includes parametric equations and polar coordinates, vectors, vector-valued functions, functions of several variables and partial derivatives, and multiple integrals. While the engineering students were not originally required to take Calculus III, this course was still used as a starting point in designing their third semester of calculus. The Engineering Calculus III includes the topics from the traditional version, but omits or deemphasizes a few sections, such as surfaces in space, parametric surfaces, and limits and continuity. These omissions make it possible to cover multiple integrals. Topics of particular interest to engineering students in the course include curvature, linear approximations of functions using tangent planes, and using vectors to calculate work and torque.

Deciding On a Placement Exam

In the first three years of the engineering program, students were placed into a math class (Calculus I or Precalculus) based upon a combination of factors that included their math SAT score, their grades in high school math classes, and the highest level of math they had completed in high school. There was no test or formula used, but rather leaders from the two departments examined each student's record and came to agreement on the appropriate math course in which to place each student.

The members of the EMC felt that improper placement may have contributed to some students' poor performance in their initial math course. Thus, alternative placement approaches were examined. One of the math faculty members on the EMC found a test, ALEKS⁶ that had proved successful at another university and proposed that we consider use of ALEKS for placing engineering students into their initial math course. Representatives from ALEKS were able to put us in touch with faculty from University of Illinois at Urbana-Champaign, one school where ALEKS had been used successfully. After speaking with faculty from UIUC and discussing specifics of the test, the EMC decided that ALEKS would be the placement tool utilized to place incoming freshmen into their initial math course beginning in the fall 2007.

Since East Carolina University requires incoming freshmen to attend a 2-day orientation session the summer before they arrive on campus, the Engineering Department tried to coordinate ALEKS test taking with orientation. Due to time and space limitations, this was not possible. Instead, email was used to contact all incoming engineering freshmen. They were given detailed instructions about how to log into ALEKS and take the placement test. They were told that to facilitate the creation of their schedule, it was best to take the test prior to attending orientation. This was not always possible. However, prior to the start of the Fall 2007 semester, all incoming freshmen had taken their ALEKS test. Although there is a charge for taking ALEKS, students did not have to pay the fee. The Department of Engineering paid for each student to take ALEKS once and also paid for remediation and a second test for students who desired a retake.

In the fall 2007 semester, students whose ALEKS score was 50 or above were placed into Calculus I, and those whose score was below 50 were placed into Precalculus. Students were allowed to appeal their placement, and some students who had taken AP Calculus in high school but did not do well on ALEKS were allowed to take Calculus. Not too far into the fall 2007

semester, it became evident to the Precalculus instructors that some of the students who placed into Precalculus did not have the mathematics background to succeed in that class. Although there were good results from the students who placed into Calculus (see Figure 1), there were a number of students who were unable to pass Precalculus. This led the EMC to believe that there may need to be a second line established for ALEKS scores. Students who scored below the lower cutoff would be placed into College Algebra with the understanding that in order to complete the engineering curriculum, they would have to be on a 5-year plan.

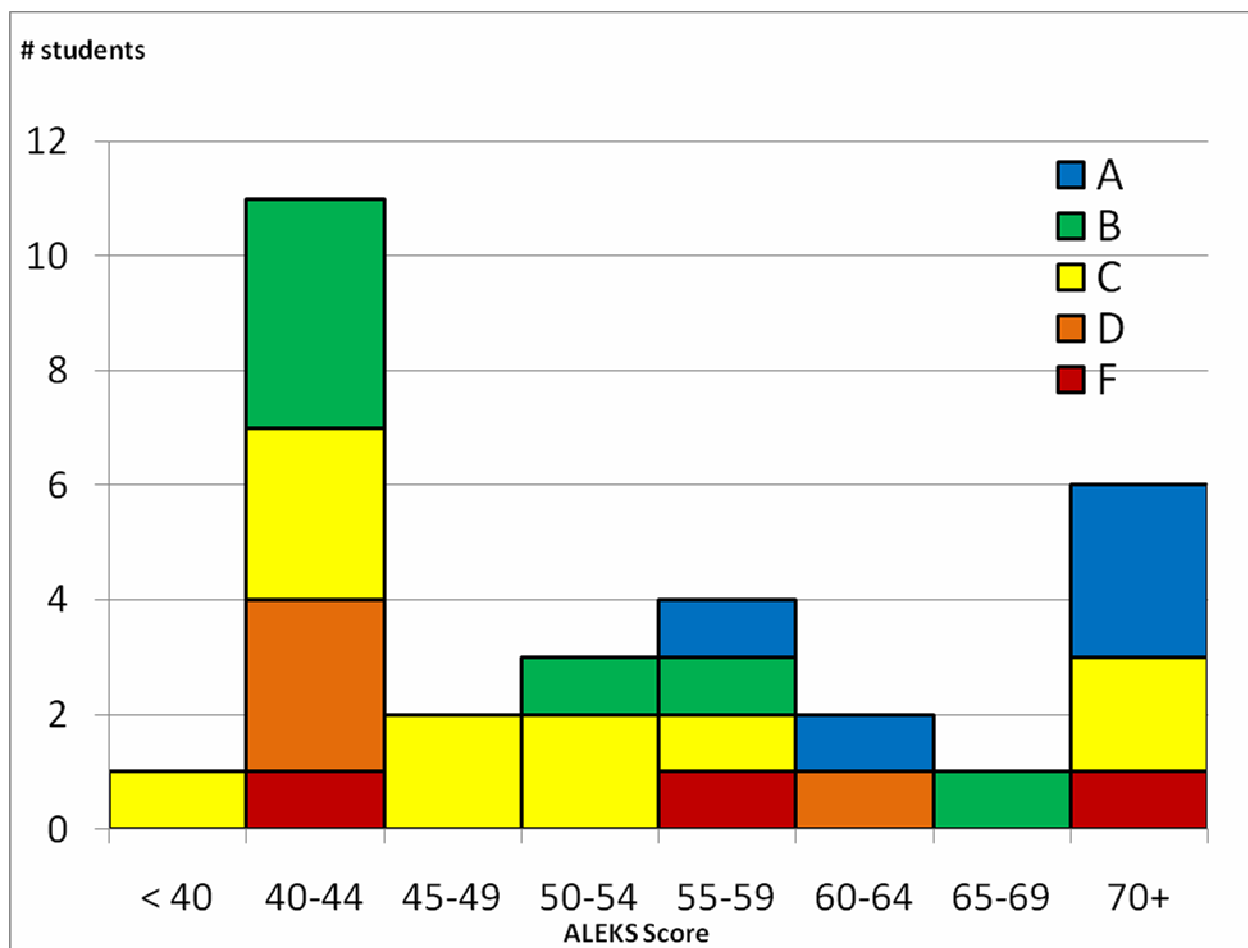


Figure 1 - Grade Distribution vs. ALEKS Score, Calculus I (2151), Fall 2007

The EMC realized that it might be advantageous to advertise the ALEKS scoring cutoff lines so that students would know what they were shooting for. Also, some students might be motivated to retake ALEKS if their initial score was within a few points of one of the lines. So, for testing over the summer of 2008, the ALEKS lines were modified and advertised. Students who scored 55 or higher were placed into Calculus, students who scored below 40 were placed into College Algebra, and students who scored in between 40 and 55 were placed into Precalculus. These cutoffs were based partially on the Calculus I grades from the previous fall semester (see Figure 1). Placements were more strictly enforced in an effort to help students be more successful in their initial mathematics course.

Exchanging Information

Once the new courses were in existence and a placement mechanism was established, the focus of the EMC turned to issues of student success and retention both in the new courses and in the other mathematics courses that the students would be taking during the fall of 2007. The EMC believed that extensive communication between the math faculty teaching the courses and the Engineering Department regarding attendance, test dates, and exam scores was crucial for improving student performance. The engineering CAR was the logical point person to receive the information from the math faculty and to utilize it in efforts to improve student success in the classes.

During the fall 2007 semester, the Math department offered one section of Statistics that could be taken only by engineering students, one section of the Differential Equations and Linear Algebra course for engineering students, and two sections of the new Engineering Calculus I class which was being offered for the first time. At the beginning of the semester, the math faculty sent their test dates to the CAR so that the engineering faculty could avoid scheduling their exams at the same time. The math faculty teaching these courses took attendance during the semester and conveyed any issues with poor attendance to the CAR who then directly addressed the students who were involved. The math faculty also periodically sent homework and exam grades to the CAR who could intervene in a timely manner by discussing low grades with the students and providing assistance as needed. The two math faculty teaching the new Engineering Calculus I courses also gave common exams and had common test dates to make it easier for the CAR to coordinate these efforts. The EMC continued to meet throughout the semester to monitor the progress of the students and to discuss the courses. This proved to be a very effective and efficient way of resolving issues before they became larger problems. It was most often the case that students who were having difficulty in their math courses were having trouble with the engineering program as a whole, so math was no longer viewed as the impediment to student retention that it once had been.

Assessment

There are two main forms of assessment that take place in the mathematics courses⁷. The first is indirect assessment, which occurs at the end of each semester. Students complete a survey describing how well they think they have met the objectives of the course. At the recommendation of the engineering faculty on the EMC, the mathematics faculty agreed to perform indirect assessment in all five mathematics courses (Calculus I, Calculus II, Calculus III, Differential Equations and Linear Algebra, and Statistics I). Since Precalculus is not a part of the required engineering curriculum, assessment was not requested for that class. As an example of indirect assessment, the student survey from Statistics I is given in Table 1 below.

Direct assessment also occurs in the mathematics courses. It consists of nested test questions that are intended to be similar to the types of questions engineering students will see when they take the Fundamentals of Engineering (FE) exam during their senior year. Currently, direct assessment occurs in the Differential Equations and Linear Algebra course and in Statistics I. Table 2 provides sample results for nested FE questions that appeared on the Statistics I final exam in the spring 2008 semester.

Table 1 - Indirect Assessment - Student Survey Results - Statistics I - Spring 2008

Rating Scale: 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree

<i>Course Objective</i>	<i>Average Rating</i>	<i>% Ratings 4 or 5</i>
I understand the role of probability in engineering applications.	4.15	85
I can calculate measures of location (mean, median, mode) and variability.	4.31	100
I understand the difference between discrete and continuous data.	4.15	85
I can define sample spaces and events.	4.31	100
I can calculate the probability of an event.	4.38	100
I can calculate the probability of an event, given that a prior event has occurred (conditional probability).	3.92	69
I understand the concept of a random variable.	4.46	100
I understand and can analyze discrete and continuous probability distributions.	4.00	85
I understand and can analyze joint probability distributions.	3.85	77
I can calculate the mean of a random variable	4.46	100
I can calculate and explain variance and covariance of a data set.	4.00	69
I can choose the appropriate discrete probability distribution for a given application, and calculate the probabilities using that distribution.	3.54	54
I can choose the appropriate continuous probability distribution for a given application, and calculate the probabilities using that distribution.	3.54	46
I understand and can explain random sampling and sampling distributions.	3.92	85

The Engineering Department set 60% as its target for FE-style questions that are utilized for assessment purposes. From Table 2, we see that questions 1 and 4 exceed the target; however, questions 2 and 3 are below the 60% correct mark. Careful examination of the FE-style questions revealed that the wording of these questions was different than the wording in the textbook. It was thought that students had become accustomed to the wording style used in the text and may have misinterpreted the questions in the given FE-style. In future offerings of the Statistics course, attention will be given to the wording of probability word problems in order to enable students to become used to the FE-style questions prior to seeing them on the FE Exam.

Assessment involves more than simply performing indirect and direct evaluation of student performance. As explained above for the example of direct assessment given in Table 2, the results of these surveys and questions must be examined by the faculty who teach the courses so

that they can determine if modifications to course content are needed. In an effort to keep assessment data organized, the EMC has created binders for the math courses. These binders contain syllabi, ample student work, assessment data, and analysis of assessment data. The math faculty members have demonstrated a commitment to the assessment process and have worked closely with the engineering faculty to maintain a record of continuous improvement activities.

Table 2 - Direct Assessment - Nested FE Questions/Results - Statistics I - Spring 2008

<u>Problem</u>	<u>Topic</u>	<u>% Correct</u>
1	probability	71%
2	probability	53%
3	probability	47%
4	sample variance	76%

Continuous Improvement

The first offering of the new engineering calculus sequence is now complete as Engineering Calc I was offered initially in fall 2007, Engineering Calculus II in spring 2008, and Engineering Calculus III in the fall of 2008. As a group, these courses cover essentially the same material in 9 hours as the traditional three course sequence did in 12. But to accomplish this, some modifications were made in the original syllabus for each of the new engineering calculus courses as the courses were first being taught. In Engineering Calculus I, the course ended with applications of derivatives instead of an introduction to integration with all material on integrals delayed until Engineering Calculus II. To compensate for this, the treatment of series in Engineering Calculus II was very streamlined. It included sequences, the definition of series, the p-series test, absolute convergence and the ratio test. Power series did not receive an in-depth treatment but integration and differentiation of power series were discussed as were basic examples of Taylor and Maclaurin series. Most of the convergence tests for positive series were omitted. In Engineering Calculus III, the material was covered as in the original syllabus. But the faculty teaching the course met after the course concluded to discuss how the material and examples covered in each section could be adjusted to allow for a more thorough coverage of double and triple integrals. These changes should also make it possible for vector fields and line integrals to be added to the syllabus the next time the course is taught – these topics were not included in the original Engineering Calculus III syllabus.

The math faculty members were particularly interested in how the students were impacted by the extensive inclusion of examples from engineering and by the web-based homework. Using MathZone was critical in allowing for the courses to cover the material since it replaced in-class quizzes and also helped the students learn the material outside of class. The results from the indirect assessment show that a definite majority of students agreed or strongly agreed that the engineering applications and MathZone were effective. The relevant questions are summarized in the following table which includes results from the two initial sections of Engineering Calculus I, Engineering Calculus II, and Engineering Calculus III.

Table 3 - Indirect Assessment – Engineering Applications and MathZone

Rating Scale: 5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree

<i>Course Objective</i>	<i>Average Rating</i>	<i>% Ratings 4 or 5</i>
Engineering Calculus I (37 responses, 2 sections)		
I am able to apply differential calculus to solve engineering problems.	3.73	70.3
I found MathZone to be a valuable resource for this course.	3.64	64.7
Engineering Calculus II (36 responses, 2 sections)		
I am able to apply integral calculus to solve engineering problems.	3.94	86
I found MathZone to be a valuable resource for this course.	4.19	81
Engineering Calculus III (37 responses, 2 sections)		
I am able to apply multiple integrals to solve engineering problems including double, surface, and triple integrals.	3.89	81
I found MathZone to be a valuable resource for this course.	3.88	76

Impacts of Committee*Curriculum*

The formation and existence of the EMC have had a clear and positive impact on the mathematics curriculum in the Engineering Program. Through careful planning, the committee created the new engineering calculus sequence which covers essentially the same material as in a traditional Calculus I-III sequence but does this in 9 hours instead of 12, meeting the overall needs of the program. Because the courses emphasize engineering applications, these courses are also more relevant and meaningful to the students. Since the first offering of the full Engineering Calculus I-III sequence has just concluded, the EMC has not yet been able to fully evaluate the impact of these courses on the performance of the students in upper level engineering courses that require knowledge of calculus. However, there has been positive feedback from the engineering professors who teach Dynamics and Statics. In conversations with engineering members of the EMC, these professors have stated that they have seen an improvement in the calculus skills of their students. The EMC intends to pursue this further by gathering data on student performance in the upper level classes as it pertains to calculus. Analysis of this data, in addition to input from the professors in these courses, will be utilized to further revise and improve the syllabi of the new calculus courses.

Communication

In a university setting, it is common for one department to provide service courses for students in a program outside that department. However, when there are problems with the courses not meeting the needs of the students in the program, such problems can be difficult to fix in a timely way through the usual administrative channels. The EMC has provided an opportunity for the

engineering and mathematics faculty to work together on the central issues of course content and design, placement, assessment, and student retention and success. The direct interaction that has occurred on the EMC has provided a very efficient way of making progress on these issues, since the engineering faculty members have immediate knowledge of the needs of the program and the math faculty members know what is feasible with regard to curriculum, faculty time for assessment, etc. With communication established, the EMC has also worked on several ancillary problems such as finding appropriate tutors and deciding which Precalculus course the students should take.

Student Performance

After the fall 2008 semester, grades data were available for 3 semesters of the new engineering Calculus I course (MATH 2151) and for 6 semesters of the former Calculus I course (MATH 2171). Figure 2 below shows a comparison of the percentage of students who earned each grade for these two courses, combined over all semesters. In the figure, the 2151 data represent 113 students and the 2171 data represent 72 students. While it is still the case that not all engineering students are succeeding in Calculus I, the data seem to indicate performance improvements. Further analysis will occur as data become available.

Conclusions

The EMC has been in existence for about two years, and in that time the committee has made great progress in improving the experience of the engineering students taking mathematics courses. Initial data from indirect assessment show that the students have appreciated the engineering focus in the new calculus sequence. Initial data on placement and grades show that the EMC's efforts are having a positive effect on student success. Now that the lines of communication between the engineering and mathematics departments exist, the EMC will continue to work on enhancing the mathematics component of the Engineering Program.

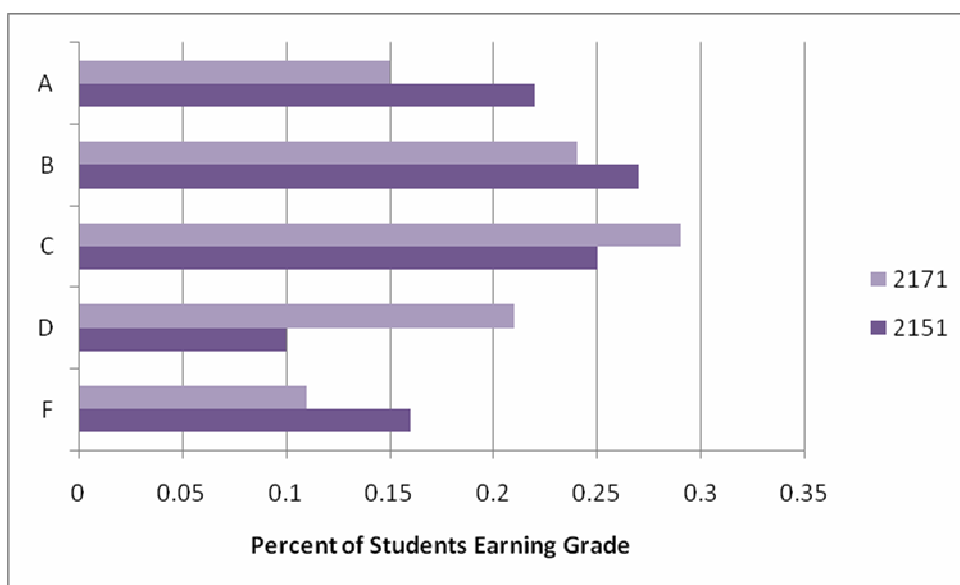


Figure 2 - Grade Distributions for Old (2171) and New (2151) Calculus I

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