AC 2008-1204: TEACHING MATHEMATICS TO ENGINEERING TECHNOLOGY STUDENTS: MOVING MATH INSTRUCTION INTO THE DEPARTMENT

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Teaching Mathematics to Engineering Technology Students:
Moving Math Instruction into the Department

Abstract

Decisions by university administrators caused our engineering technology department to make a transition from the university's main campus to a satellite campus and becoming an evening program operating on accelerated terms. This has forced many changes on the department, including changes in how our students get the necessary background in mathematics.

To understand the content in the major courses and to meet standards for bachelor's degree programs in engineering technology, students must be able to use material from algebra, trigonometry and differential and integral calculus. In the past, we have met these needs by requiring specific math department courses.

With the move to the satellite campus, math courses became an issue for our program. At this campus, very few students need math beyond minimum bachelor's degree core requirements. Higher level math courses suffered from low enrollment. Also, a math instructor could generate higher enrollment and give a better return to the university by teaching a basic core course. As a result, few math courses meeting our needs were scheduled. Also, due to pressure to offer more web courses, some of the higher level math courses usually appeared as online courses. This combination of limited offerings and web courses proved to be difficult for our students.

It became evident that the best way to ensure that our students got the necessary math background in a timely manner was for us to teach the math topics within the department. The department would control scheduling and be responsible for staffing. The department would be responsible for content, and the courses would be focused on topics needed in our courses and in later practice.

Two new department courses were developed to cover topics from algebra, trigonometry and calculus. These courses were first offered in 2007. Math topics are also included in two existing courses, an introductory course for new students and an upper level course that covered advanced math topics and calculation software. To meet university core requirements for one regular math course, the department added a requirement for statistics. This course meets core requirements, the university offers an acceptable number of sections at our campus, and it covers material that students need in practice.

This paper will discuss the author's experiences with making the transition from the use of math department courses to developing our own courses in mathematics for engineering technology. The paper will discuss development of the courses, initial offerings, a discussion of the effects this change has had on other courses, and plans for future changes.

Introduction

During the 1980s, our institution replaced an industrial arts program with a bachelor's degree program in engineering technology. The program was formed on the university's main campus,

where students had easy access to course offerings from the math, chemistry, and physics departments, and operated on traditional 16 week terms. This transition was completed in the early 1990s. In 1996, the administration decided to relocate the program to a satellite campus on a military installation (Fort Campbell, KY).   While the move was described as an extension and the department was still expected to serve students from the main campus, requirements had to be such that students could complete the entire program at the satellite campus.

The satellite campus serves a mix of students including active duty military personnel, dependents, retired military personnel, and civilians. Many of the students are older than traditional college students, work during the day, and are restricted to taking courses at night or by video, web, or other asynchronous options. The department shifted from offering courses primarily in the daytime to offering all courses in the evening, and shifted from sixteen to accelerated eight week terms. While we could count on math courses being offered to support not only engineering technology but also math, physics, and other departments on the main campus, higher level math course sections at the satellite campus had to be justifiable based mostly on engineering technology enrollments.

Before the move, the department had very stringent math requirements for engineering technology programs. The requirements included a course in trigonometry and two courses in calculus. These courses, one in differentiation and one in integration, were also required for math and physics students and were equivalent to 1st year engineering school requirements. Each course was offered as a 5 credit hour course, and the courses were very difficult for students taking courses in 16 week semesters. These courses were impractical for 8 week semesters, and the department was forced to drop these requirements and require instead a simpler three credit hour calculus course offered primarily for business majors. Also, the department developed a second course which included some material from calculus.

At the satellite campus, many of the students are not as strong in math as students who have just graduated from high school, and some have a degree of math phobia. Prior to taking calculus, students were required to take courses in college algebra and in trigonometry. The college algebra requirement was added to help students who were either weak or rusty in math.

At that time, college algebra met university core requirements. Many students took college algebra to meet core requirements, and offerings were plentiful. More recently, a state board mandate forced the university to reduce the number of courses accepted to meet core requirements, and the college algebra course was dropped from the core list. Instead of college algebra, most students either took statistics or a math course specially designed for majors that do not have significant math needs. Limited resources such as classrooms and math faculty were assigned to the courses promising the greatest enrollment, and college algebra offerings soon became scarce.

Even when we could easily get students into the college algebra course, the trigonometry and calculus courses supported primarily engineering technology students. Generally, the courses would be offered once or twice a year on our campus. The math department was under pressure to offer courses on-line, and, often, the sections offered for our students were web courses. This proved especially challenging, as well as unnerving, for many of our students.

With regards to staffing for math courses needed for our program, our department attempted to assist by having one of the authors teach math courses. Initially, this was accepted by the math department. However, due to concerns in the math department over requirements that math faculty have a set number of graduate hours in mathematics, this practice had to be abandoned.

By the fall of 2005, it was becoming increasingly evident that the department had to do something different to get our students the foundation in mathematics necessary for the major courses. This issue was considered as part of a broader curriculum review in 2005-6. The authors recommended to the rest of the department that we develop two courses within the department to cover needed topics from algebra, trigonometry, and calculus. Students at the satellite campus could take these courses in place of the current requirements for precalculus and calculus. This would allow the engineering technology department to control scheduling and be responsible for staffing at the satellite campus. The department would determine the course content, and the courses would be focused on topics needed in our courses and in later practice.

Two new department courses were developed to cover topics from algebra, trigonometry and calculus, and the courses were first offered in 2007. The paper will discuss development of the courses, initial offerings, a discussion of the effects this change has had on other courses, and plans for future changes.

Course Development

The issue of mathematics requirements was an important part of the curriculum review. All members of the faculty were aware of the issues with the math department courses and with the resulting difficulties for our students. The faculty quickly reached consensus and agreed to the new courses. Two courses were approved. The first was given the name "Applied Mathematics in Engineering Technology," and covers material from algebra and trigonometry. The second, "Applied Calculus in Engineering Technology," covers material from differential and integral calculus. The first is used as an alternative to a math department precalculus course, and the second is an alternative to their three credit hour calculus course. The courses were similar to courses already in use for the departments associate's degree program in electronics technology, but would be designed to support all areas of our multidisciplinary program.

To meet university core requirements, all students must complete at least one regular math course. The department added a math course in statistics to the curriculum which would satisfy this requirement. The basic statistics course meets university core requirements in math, and the math department offers an acceptable number of sections at our campus. The statistics course covers material that is very valuable for our students. One of the authors had wanted to add statistics to the curriculum in the past, but limits on the number of credit hours precluded this addition. This replaced the old requirement for a college algebra course.

The new departmental courses were not to compete directly with the math department courses, but to offer an alternative to these courses on the satellite campus. The department requirements were modified to allow students to take either the new department course or the math department course to meet a requirement for math at the precalculus (algebra and trigonometry) and

calculus. Students coming into the program on the main campus are advised to take the math department courses in precalculus and calculus, while students at the satellite campus take the new engineering technology courses. After the new courses are fully established, it will be of interest to assess and compare the preparation of the students who go through the math department courses and those who go through our department courses.

Course Content

After reaching the decision to create the courses, discussions continued in the department to determine course content. The intention was to create courses that would focus on topics that were needed for later courses and for industrial practice, rather than to just copy the content of the math department courses. As a group, the faculty discussed the specific content based on needs in later courses. The group also discussed textbooks, and identified a book, Basic Technical Mathematics with Calculus,[1] that could be used in both courses.

The first course – Applied Mathematics in Engineering Technology - was designed to cover topics from algebra and trigonometry. After discussion, some topics from geometry were included as well. Currently, the course covers the following topics:
-   Areas and Volumes of Geometric Shapes,
-   Functions and Graphs,
-   Trigonometric Functions & Graphs,
-   Right Triangles, including
    o   the Pythagorean theorem, and
    o   the six trigonometric functions as ratios of the lengths of sides; solving for unknowns in a right triangle,
-   Vectors; Addition of Vectors,
-   Linear and Nonlinear Equations
-   Linear Equation & Determinants; solution of simultaneous equations by calculator using matrix methods,
-   Solution of Quadratic Equations by the quadratic formula and by graphical methods using a graphing calculator,
-   Exponents and Radicals,
-   Complex Numbers,
-   Exponential & Logarithmic Functions,
-   Solving Equations with Unknown Exponents using Logarithms
-   Finding Roots of Higher Order Equations by Calculator
-   Solving Inequalities Graphically and Analytically
-   Variation & Trigonometric Formulas of Double and Half Angles.

Some topics receive more emphasis than others based on needs in later courses and in practice.

The list of topics reflects specific needs in other courses. All instructors expect students to be able to manipulate equations to find unknowns. Students should develop these skills through practice with many of the topics in this course. All students need to understand the basics of functions, including linear, power, and exponential functions, and graphs on linear and logarithmic scales. All students are required to take one course in statics and strength of materials. Also, some students take courses in plane surveying or dynamics. These students all

need to be able to work with right triangles and vectors. Students taking courses in electronics need preparation in matrix methods and in calculations with complex numbers. In all areas, the course emphasizes the use of topics from mathematics as tools to solve technological problems and the use of graphing calculators.

The second course – Applied Calculus in Engineering Technology – arguably has a less diverse list of topics. Basic differential and integral calculus is expected in the math content of bachelor's degree programs in engineering technology,[2] and this course was developed to meet those requirements. The course focuses on the basics of differential and integral calculus in one variable, and on using tools such as tables of rules for taking derivatives and tables of integrals to find solutions to problems. As the goal of the course is to prepare the student to find a derivative or the solution to an integral when needed in later courses or if needed in practice, proofs and methods used to find the solutions that go into the integral tables are not emphasized.

The authors teach some of the engineering technology courses where students need to use tools from calculus. We require a thermodynamics course of all majors and we do use calculus when developing tools for work in expansion and compression processes. Some of our students are required to take a course in dynamics, where derivative and integral operations are used to find equations for position, velocity, and acceleration. In working with these problems, we expect students to be able to use rules of differentiation to find the derivative of a function. We expect students to be able to look up and use solutions from an integral table. We do not expect them to use l'Hospital's theorem and take limits or to perform integration by parts. We consider it unlikely that a graduate would have to face problems requiring these tools in practice and, if such a problem was encountered, we expect that an engineering graduate, who had been required to go well beyond our requirements in mathematics, would be available to deal with that task.

Initial Course Offerings

The new courses had received the necessary approval at the department, college, and university levels and could be offered starting in 2007. To date, the department has offered the applied math course twice and the applied calculus course once. Both courses will be offered twice each year. The response from students has been positive. They have been able to get the needed math courses in a timely manner, and they have responded well to the courses as taught by an engineering technology faculty member.

To date, we do not have enough experience with this course to make any comparisons between students taking math in the department courses and students taking math department courses. When these courses have been fully established, the authors anticipate making comparisons between students taking math department courses on the downtown campus before coming to the satellite campus and students taking the engineering technology math courses.

Instructional Format

The courses are taught to emphasize the use of mathematics as a tool to solve practical problems. Graphing calculators are used extensively, and both analytical and graphical (visual) methods are used. Students were encouraged to solve problems analytically and then check graphically or

vice versa. Texas Instruments graphing calculators are required for math courses at our university, and students in this course used TI calculators as well. There were no restrictions specified for the calculators. While the TI-89 is the most powerful of the calculators used and can be used to solve complex algebra problems, students can use TI-86 or lower versions of TI calculators.

While some time is spent in lecture presenting material, students are expected to learn by doing and work problems while in the classroom. This gives better assurance that students are learning how to use the tools being taught throughout the course. In the most recent offering of the applied math course, more use was made of on-line resources. On-line test generation software was used to generate handouts of fifteen questions from the relevant chapter for each class. The instructor would do some of the problems from the handout and review the relevant sections from the text. Students would then do other problems from the handout. The students appeared to appreciate this approach, where they got to practice the material while the instructor was present to help. This worked well, and the instructor is planning to continue efforts to use on-line resources in instruction.

Impact on Other Courses

The first group of students who completed the engineering technology applied math courses are just reaching the upper level courses. As students who have taken the department's applied math courses move on into engineering technology courses requiring math, we look for feedback from the other instructors on the student's preparation in mathematics. The content, emphasis, and possibly instructional techniques in the applied math courses will be modified if problems are identified with student preparation from our courses. Also, content may be modified if new topics are identified that are needed for the later courses or for industrial practice.

Math topics are also included in two existing courses, an introductory course for new students and an upper level course that covered advanced math topics and calculation software. The introductory course covers systems of units, unit conversions, and basic calculations using units.[3] Math content from this course compliments the first new course.

The authors hope to be able to modify the content in the upper level course. This was initially designed to include both computer tools and material from the engineering-level calculus course when the department was forced to drop that requirement and replace it with the three credit hour business calculus course. The course was to emphasize problem solving, and was not to be limited to mathematical problem solving or computer tools. In practice, students have come to the course without the expected capabilities in calculus, particularly in integration, and too much course time has been required to teach the use of integral tables. This is perceived to be primarily a problem for students who took the math department course in our accelerated eight week terms. The authors hope that students taking the new applied calculus course in the department, with its emphasis on finding solutions for derivative and integration problems, will not need to have this taught to them in the upper level course. With that burden removed, we can concentrate more on software and on broader issues in engineering problem solving than those which can be reduced to math problems.[4]

Future Directions

With the emphasis on using tools from mathematics to solve practical problems, the authors seek to emphasize the use of graphing calculators and other tools that students will be expected to use in the workplace. One area for development here is to integrate computer software packages into the course. We currently use the EXCEL spreadsheet in the upper level problem solving course, and may move that into these classes for graphing and other uses. The department has purchased MATHCAD software, and will be working this into courses. As we develop experience with MATHCAD, it is likely that we will bring it into these classes.

With our student population, there is a need for asynchronous course options. With the use of on-line tools for instruction, it may be possible to offer this course on-line or in some other format that does not require students to attend traditional classroom sessions. While the course is still new in the classroom, it will be some time before we attempt to offer the course in alternative formats.

For some time, it has been a concern of the authors that, while students can get help from the professor in the classroom and at the professor's office, many of our students do need help outside of class and cannot match their schedules to the professor's office hours. We would like to offer our students an option for tutoring outside of class. With the use of on-line tools in the classroom, it may be possible to set up a math lab for our students using on-line tutorials and upper level students hired to assist in that lab. This depends in part on the available on-line tools and on funding for student workers. If this can be arranged and coordinated with these courses, it would be of great help to our students.

Assessment is an important issue for the department, both internally and for accreditation purposes. The instructors are getting enough experience with the course and enough students are passing through the courses for us to consider ways to assess both the outcomes from our courses and to compare these outcomes with the outcomes for students who take the traditional math department courses on the main campus. This assessment should be done in classes that make use of the tools from mathematics in all concentrations, and will be very valuable in telling us how we are doing and what we should change. Also, it will be of great interest to have a measure showing us how student preparation compares between our courses and the math department courses.

The courses do need to keep pace with needs in the workplace. Through periodic meetings and reviews of our curriculum, we look to our industrial advisory board for guidance on their needs. Based on their responses, some topics may be emphasized less or dropped, while new needs will be added to the course content. We look for their guidance both on content and on tools such as graphing calculators and software.

Conclusions

Circumstances led our department to move from requiring all students to take courses from the math department covering necessary topics in algebra, trigonometry, and calculus to offering an alternative with two engineering technology courses. These courses have been developed to

emphasize specific topics from mathematics needed for our courses and for our graduates in practice. The courses have been added to the curriculum and our perception is that they were well received by the students. As students who have taken these courses move on into other department courses where they must use their math skills, we will have the opportunity to assess our instruction and to compare results from our courses and from the original math department courses. Over time, the courses will be modified based on assessment results, new needs from industry, and new software packages and other tools for instruction and for solving math problems in practice. This process will be internal to the department, enhancing our ability to respond to feedback calling for change.

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