2006-1967: INITIAL DEVELOPMENT OF A NEEDS-DRIVEN COURSE ON CALCULATION METHODS AND PROBLEM SOLVING FOR ENGINEERING TECHNOLOGY STUDENTS

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Initial Development of a Needs-Driven Course on Calculation Methods and Problem Solving for Engineering Technology Students

Abstract

As part of a major curriculum overhaul, our department added a course – ENGT 3050 Problem Solving in Engineering Technology – which was designed to cover skills that we felt students needed to have before leaving our program and that they were not getting from other courses. Most of our curriculum is structured around standard course topics and texts. This course was a departure from that model. In selecting the content for the course, we focused on topics that were not clearly being covered in other required courses and that students needed to know before reaching the workplace. This paper will discuss the author's experience in the initial development and offering of this course.

In its current form, much of the content is based on using math and computer software in the process of solving problems. Based on our current degree requirements, the course content includes topics on graphing and presenting data, data reduction, and basic topics from statistics. Our curriculum overhaul included removal of engineering-level calculus requirements. With this change, some needed material was cut, and the new course covers this to some degree. Overall, the course serves in part as a capstone to our math requirements, with a focus on how to apply the math studied in applications.

As envisioned, the course also includes a balance of material on creative problem solving. In practice to date, the course is too heavy on math content, especially in the area of calculus. This has occurred because we are finding that the students have not learned how to use the material studied in the required calculus course. Experience with this course is giving us information on what our students are not learning to use from their math courses, and gives us guidance on how to change the way we teach math skills to our students. With improvement in that area, we can focus more on the broader aspects of solving problems in the workplace.

Introduction

Our department was moved from the main campus to a satellite campus. For several reasons, including differences in term length and student populations, we could not expect some of the courses we had required on the main campus to be offered successfully at the satellite location. We had to change our requirements to adapt to the new site. The changes included a reduction in calculus requirements (from ten to three credit hours) and elimination of a computer lab where we had introduced students to the EXCEL spreadsheet and other software.

Some of the changes and cuts reflected a need to better align our requirements with engineering technology, rather than engineering, requirements. However, the changes did cut some material we deemed valuable to our students. We added a new course, ENGT 3050 Problem Solving in Engineering Technology, where we would have a chance to cover this material. This is designed as a third year course, and the required math department course sequence is a prerequisite. The

new course would serve as a capstone to the math courses, with an emphasis on using these tools, as well as computer tools, in problem solving.

Course Topics

The ultimate goal for the course is to focus on the broad aspects of problem solving in engineering technology. In its current form, however, the course was developed by looking both at material cut due to changes in other requirements and at specific skills that students should have when they leave our program.

The topics selected for the course fall into three categories: graphing and presenting data, basic topics from statistics, and some topics from calculus with basic applications. Students are expected to be able to use basic electronic tools for calculations: graphing calculators and computers with the standard Microsoft Office software package.

In the graphing and statistics parts of the course, the EXCEL spreadsheet is used as the primary tool. While the graphing calculator will also perform many of these functions, the EXCEL software has several advantages. While graphing calculators will do much of this work, we do not require students to own a particular brand or model of calculator. The EXCEL package gives us a standard platform for instruction, and a platform that gives a full computer screen sized image, information can be saved in standard computer storage devices, and output can be printed on standard printers. This standard platform will also be available to students in the workplace. While some employers in our area use MINITAB or other specialized software packages, different companies use different packages. We can count on all of them having and using EXCEL and other standard Microsoft Office products.

While the course focuses on specific tools in graphing and statistics, one goal here is to have students learn how to find and use new features on their own. The number of functions and features available on EXCEL is far too great for any one course to cover more than a small fraction of the software's capability. Also, new features are added with each new issue of the software. It is important for the students to learn how to learn on their own. Hence, students are directed to use the integrated information and help features in the software while learning to use tools presented in the course.

Graphing

The graphing portion of the course focuses on using graphs as tools for interpreting data and for presenting data to others. Topics range from the relatively simple generation of pie and bar charts to plotting with logarithmic scales and using regression tools to find best-fit equations for data.

Our student population is a mix of traditional college age students and older students. Many students come to this class with some knowledge of EXCEL. The younger students have used EXCEL, some even in primary school. Some of the older students have used EXCEL, either at work or while in the military. Others have little or no experience with the software. The pie and bar chart assignments are relatively easy. The challenge here is for the student to learn how to

tailor the graph to be what they want, rather than what the software creates based on the default settings. As the results from the default settings can leave much to be desired, this is an important skill for the students to learn. Tailoring the graph often takes more time and effort than creating the graph itself. Some students have had experience creating x-y plots of data, while others find this more challenging. Few if any students have had any experience creating graphs with logarithmic scales, although some do recognize the form from either other courses or graphs encountered at work.

Prior to the evolution of computer tools, the logarithmic plots were used to give a visual check on the type of relationship between x and y values. A reasonably straight line on a given set of axes indicated a specific type (linear, power, exponential) between the independent and dependent variables. Tools such as the TRENDLINE function in EXCEL let one generate an equation and a measure of goodness of fit. This reduces the need to create the graph. However, the graph is quite easy to produce, and a visual inspection can tell the user more about the match between the function and the data, especially for possible use in extrapolation. Also, the graph is useful for visualization. Thus, the course includes both graphing in different forms and the use of TRENDLINE to find equations for the data.

Most of the problems assigned for this topic give the student a table of data and require the student to enter the data and create the graph. Students are required to decide on the type of graph, and on how the graph should look when finished. There is room for variation here. In some problems, the students are expected to create a spreadsheet for calculations, and then plot the results. On exams, these tasks are usually separated, so that a student who is having difficulty creating spreadsheets for calculations can still demonstrate skills in graphing.

Statistics

With the press of other requirements, we did not make room in our curriculum to require a course in statistics. Given the importance of statistical methods in process and quality control, our students need to know something about this subject. We did include topics from this area in the problem-solving course. Course topics from statistics include creating histograms and calculating measures of central tendency (arithmetic mean, median, and mode) and of variance (standard deviation). This is followed with discussion of probability distribution functions, with emphasis on normal and exponential distributions. Tasks here include basic comparison of histograms to "standard" distribution forms and determining the fraction of values above or below a given value or between two given values for a "known" distribution. The difference between samples and populations is discussed, but time constraints have kept us from covering tests for sample size. The EXCEL spreadsheet is used for all calculations. Students are also taught to use printed tables for the normal distribution function. The exponential distribution can also be used as an application of integration.

For this topic, some problems come with data for a sample. Students must enter the data, and then use spreadsheet functions to find various values. Students can also use this data to create histograms. For this, they must make decisions on the number and size limits for bins in creating the histogram. While students can use means and standard deviations found from the data with

the normal and exponential distribution functions, most of the problems here start with a given distribution and values.

In grading tests, it is necessary to look at the student's saved file and confirm that they really did use the spreadsheet function to find the values. In some cases, students who were having difficulty used other means to find the numbers, and then only entered the values. As the goal is to see that the student can use the spreadsheet for this work, using another tool defeats the purpose.

Calculus

ABET guidelines[1] for bachelor level Engineering Technology programs include calculus. In math, our requirements changed from ten credit hours of engineering school level calculus and analytic geometry to a three credit hour calculus course designed primarily for business students. This course did not include the same content in analytic geometry and graphing, and did not require trigonometry as a prerequisite.

As planned, the new course was to pick up some calculus topics. This was to be a very small part of the course, roughly one week of material in an eight-week term. From their basic calculus course, students were expected to have learned how to use tables of derivatives and integrals to find answers to basic problems. They were also expected to be able to arrange a simple derivative relationship to form an integration problem, such as using a function for velocity as a function of time to find a relationship between position and time. As the new calculus course did not require trigonometry, the main topic was to be coverage of table solutions for basic derivatives and integrals including trigonometric functions.

Experience showed that these expectations, sadly, were far removed from reality. The calculus class is taught in eight weeks. While the course description includes integration, students report that the class spends very little time on that subject. What time is spent in integration comes at the end of the term, and student retention is low at this point in the course. After disappointing early runs with the new engineering technology course, I took to giving a calculus assessment test on the first day of the course. Not only did this have a highly energizing effect on the students, it also gave me a clearer picture of their ability entering the course. While they have some chance of completing a simple differentiation problem, most had little or no chance of completing an integration problem. At best, students reported having seen a table of integral solutions, but had not been taught to use this tool. If the calculus portion of the new course was to have any value, we would need to spend more time on using tables to find solutions to derivatives and integrals.

As a result, calculus topics have come to take more time in this course than planned, or is perhaps warranted by needs in the workplace. The focus is to teach students to use tables of derivatives and tables of integrals. They need to be able to recognize the type of problem, derivative or integral, and to select the correct relationship(s) from the tables for solution. Also, the student should know the physical meaning of derivatives and integrals.

The basic calculus problems follow the standard math course practice of giving a function and directing the student either to take the derivative or to integrate over a specific range. Problems assigned in this course start with the most straightforward, where the problem is a direct match with a table entry, and increase in difficulty. With inclusion of problems using trigonometric functions, one type of problem will require integration of a function such as $\sin(\pi x)$ dx, requiring students to deal with the difference between the function argument and the dx term. An example of the most advanced problems would be one where the student is given the acceleration of an object as a function of time, and is expected to use definitions for velocity and position to set up and solve integrals to find the velocity and position functions.

Course Text

While texts are available for each area, no text examined covered all of these areas. The best solution was to put together a tailored text from different sources covering each major area. This option is available from several publishers, and the text was created with relative ease. Basic material on graphing and on statistics was taken from a text on engineering fundamentals[2]. Material on calculus and applications came from a calculus text[3] aimed at the engineering market. An advanced text (Gryna, Quality Planning and Analysis[4]) was tapped for more information on graphing and on statistics. Finally, a text on spreadsheet tools[5] was used for material on using the EXCEL spreadsheet. Appendix material including reviews of basic math topics, tables, and answers to homework problems were also included. The net result is a special textbook available from the regular publisher and is listed with its own ISBN number.

Perhaps the most difficult part of assembling this text was to limit the text to a reasonable amount of material for the course. The text included material from the calculus text on optimization and on vectors, as well as applications and numerical techniques. If time is spent on these subjects, too little time is left for the other primary areas. Material from Gryna[4] was included to cover quality and process control issues. This would be a valuable addition to the course if there were sufficient time. Overall, the current text includes too much material, and the cost is on a par with regular textbooks. In future revisions of the course, either the text will be reduced in size and cost or the text will be used to cover more than one course.

Initial Development and Review

The author took the lead on developing this course. The draft course package was reviewed and approved by the entire department as the department curriculum committee. The course was then reviewed at both the college level and by the university's Academic Council. After being approved at all levels, the course was added to the catalog. As with other required courses at the junior and senior levels, this course was to be offered once a year. The course has now been offered in four regular class sections with asynchronous video sections offered in parallel. Also, a few students have completed the course via independent study using videotapes from earlier regular course offerings.

Experience With the Course

The course is taught in a computer lab with projection equipment. In all parts of the course, students are expected to work along with the instructor when doing examples, and are often given time to work ahead of the presentation or to work problems ahead of the instructor. This "do as you go" approach has worked well with this material.

As noted earlier, one of the greater shocks was finding how little the students retained from their calculus course. While I teach other courses that require calculus as a prerequisite, I had yet to become fully aware of the problem in this area. These problems led to rearrangement of the material and changes in the presentation. In the latest offering, the calculus material was taken as the first topic. It was covered relatively quickly and focused on teaching the specific skills necessary to use tables. The goal is not to replicate the coverage in a full engineering or math department level calculus course. Rather, the goal is for students to be able to solve simple problems using the available tools. With this material covered, calculus problems could be assigned for practice through the rest of the course, along with the other material.

Graphing is the next major subject area to be covered. This is the first topic where EXCEL is used, and this software is used throughout the rest of the course. The first assignment has students taking given data and creating pie and bar charts. Students are expected to select the best type of chart for presenting the data, and to be able to modify the chart by selecting font sizes, deleting the legend when not needed, and using other features. Also, students are expected to update the chart with additional data, either additions to the first data set or addition of a second data set.

The course moves on to producing x-y plots using first linear and then logarithmic scales to produce linear, semilog, and loglog plots. In the process, students are also expected to create spreadsheets to perform specific calculations, including use of absolute cell references or named variables. For testing, these two tasks are separated so students are able to demonstrate the ability to create graphs even if they cannot create the spreadsheet.

The final major topic is statistics. Again, EXCEL is used to take data and create histograms, to find maximum and minimum values, and to calculate mean, median, mode, and standard deviation. Histograms and sample parameters are used to decide if a normal or exponential distribution appears to be an acceptable approximation. Finally, the spreadsheet functions are used to find percentages below, above, or in between given values for normally or exponentially distributed values.

As planned, the major quantitative material would be completed during the seventh week of the eight-week term. The goal is to then discuss more qualitative aspects of problem solving in engineering and technology, perhaps while also continuing with homework assignments over the quantitative material. In offerings to date, it has been challenging to cover all of the quantitative material, let alone finding time for other topics.

Observations

Based on experience with the course, the students have the most difficulty with the material from calculus. Their retention from the required calculus course is low, especially in the area of

integration. The students also indicate fear of the calculus material. While the course is making a difference as observed on class exams, many students are still poor in this area even after this course.

While many students come to the class with some familiarity with EXCEL, most show that they still have something to learn with this software. The use of logarithmic scales is the most troubling element of this course for the students. Also, many have difficulty relating specific types of plots (semilog, loglog) to specific forms of equations (power, exponential). It may be useful here to have students do some graphing by hand using semilog and loglog paper to drive home this point.

Perhaps the most serious omission with the current coverage of material lies in statistical tests. Also, it would be highly desirable to move into practical applications, such as development of control charts.

Overall, the course is of value to the students. Many of our students are working, either in part time internships or full time jobs. Often, students tell me that what we are doing in the class when using EXCEL in graphing and statistics relates directly to what they are doing at work.

Areas for Further Development

As described here, the initial development of the course was an internal process. While this is the most direct path for development, the course would be improved by seeking input from the industrial advisory board and from alumni on course content. This would ensure that the topics covered fit the goal of teaching skills that students need to have prior to employment.

Now that the course has been developed, more needs to be done to integrate this course with other courses in the curriculum. Currently, many students are not taking this course until their senior year. Ideally, they should be taking the course in the junior year, and applying tools from this course in other classes.

The problems solved in the course are textbook problems focused on specific areas of the course content. These are useful in teaching these specific areas, however, they are only of limited use in teaching students to see the broader picture of how these tools are selected and used in general technological problem solving. An improvement over this approach would be to structure the material around a project, where students need to select the necessary tools and where many of the tools from the course can all be used together.

Conclusions

As part of a major curriculum revision, our department added a course – ENGT 3050 Problem Solving in Engineering Technology – to cover specific skills that students needed before employment. Topics have been selected from different areas, and a tailored text drawing from several standard texts was required. This course has been a success, and students report that material from the course has helped them in the workplace.

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