AC 2008-351: ADOPTING A SUCCESS STRATEGY FOR FIRST YEAR ENGINEERING STUDENTS ENROLLED IN PRE-CALCULUS

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Adopting a Success Strategy for First Year Engineering Students Enrolled in Pre-Calculus

Abstract

In 2000, Michigan Technological University switched to a common first-year engineering program that was designed for students who were Calculus ready. Unfortunately, approximately 250 first-year engineering students (out of 1000) were not prepared to take Calculus when they entered the university. Consequently, these students had no engineering course their first semester. In 2001, an engineering course that paralleled the course material in Pre-Calculus was piloted. This course improved the retention of these students and evolved into a two semester course sequence for all engineering students starting in Pre-Calculus. Over the past two years, there has been a change in the students taking this course. The math background of these students has proven to be extremely variable and the existing courses no longer met the needs of these students. Many of these students also lacked experience using engineering tools (i.e. Spreadsheets, VBA, etc.). As such, the courses were redesigned in the summer of 2007. Previously, the courses have focused on a range of engineering software and communication tools that the students need to succeed in their upper division courses. The number of topics covered and the variety between them caused a great deal of discontinuity in the course material. Therefore, the new structure emphasizes subjects where engineering tools are used to solve or disseminate the course material in modules that are interrelated and reinforced throughout the course. In the first course, three subject modules were created for this purpose:

- Engineering Design and Analysis
- Engineering Ethics
- Engineering Sustainability

In the first course, students will use engineering skills such as the problem solving method and statistical analyses while completing design activities. They will analyze and communicate their results in a technical poster competition. The second course builds on previously learned skills with the addition of technical presentations incorporating sustainability concepts and a semester long design project. Students will design a “safe” snowball launcher and create a 3-D model of their concept using Unigraphics. They will analyze the mathematics and physics of their launcher using Excel and Visual Basic programming. Throughout the project, students will communicate their design progress in memos and a final report.

This paper will describe in more detail the design and structure of the two courses, along with the history of their development. Data will be presented on how the inclusion of engineering courses for these students has improved their retention. Student comments and instructor observations of the new course structure will be included.

Introduction

For the past seven years, Michigan Technological University has had a common first year engineering program.[1] To meet the needs of the entering engineering students, this program provides two tracks: Calculus ready students and students enrolled in Pre-Calculus. Entering first year students are placed in Calculus of Pre-Calculus based on their ACT or SAT score. Table 1 shows the math placement data for students entering Michigan Tech without transfer or AP credits for math. Approximately 75% of the entering first year students within the College of Engineering (COE) are calculus ready. Of the remaining students, over 90% are enrolled in pre-calculus. The remainder, approximately 25-30 students each fall, is enrolled in College Algebra.

Table 1: Math Placement for First Year Students at Michigan Tech

Course	Test Score Range	
	ACT	SAT
Pre-Calculus	19-25	500-590
5 Credit Calculus 1	26-28	600-640
4 Credit Calculus 1	29+	650+

The students who are ready to take calculus complete two courses: ENG1101 and ENG1102. For the students who begin Michigan Tech in Pre-Calculus, an alternate path was developed. This path consists of a three semester sequence of ENG1001, ENG1100 and ENG1102. The development of this alternate path is described in the paper by Monte and Hein.[2] This parallel path has increased the retention of the students who are not calculus ready and has increased their performance in their associated math courses.[2] Figure 1 shows the two tracks students take through the first year engineering program.

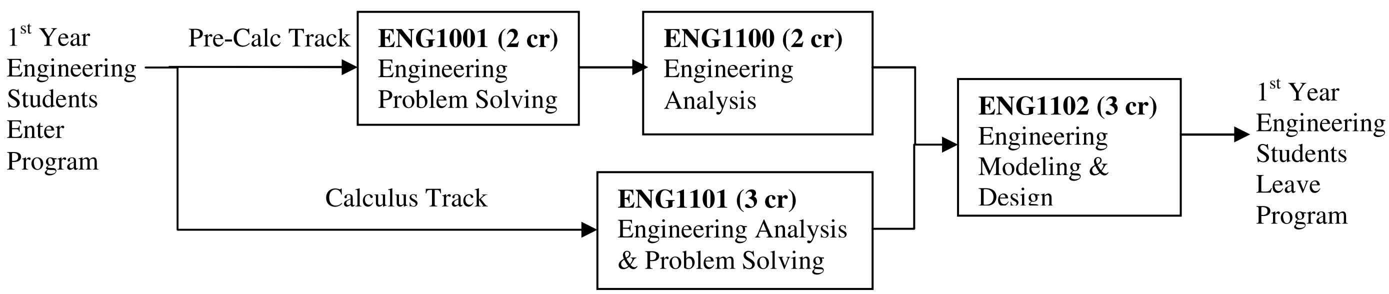

Figure 1: Course Pathways for First Year Engineering Students

ENG1001 was piloted in the Spring of 2001 to provide students enrolled in Pre-Calculus with an engineering course. The topics covered in the course were coordinated with the topics being covered in Pre-Calculus. For example, students apply the concepts learned regarding linear, power and exponential equations in pre-calculus to engineering applications in ENG1001. The students enrolled in the course elected to participate in the program. Most of these students were part of the Michigan Tech ExSEL program. ExSEL is a program that promotes students success through academic support services such as peer mentoring, study groups, study skills and time management techniques, academic progress monitoring, campus resource referrals, campus and community involvement events, and career and personal development seminars.[4] Many of the students lacked computer and basic technical skills. The course was structured to address these needs.

Initially, students took ENG1001 and then ENG1101. With the implementation of ENG1001, the retention of first year engineering students who had pre-calc as their first math class increased.

Because not all engineering students taking pre-calc took ENG1001, a performance comparison was completed between the students who took ENG1001 and those who did not. It was found that students who had taken ENG1001 performed better in ENG1101. The study showed significant differences for students entering Michigan Tech with ACT scores of 19-22. The students participating in ENG1001 outperformed their counterparts in pre-calculus. More importantly, the ENG1001 students earned fewer D's and F's than the non-ENG1001 students. With these successes, more students who completed ENG1001 continued on to calculus and to ENG1101.During 2003, the retention of the students participating in ExSEL and ENG1001 exceeded the retention of the first year engineering students, 86.4% and 85.2%, respectively.[3]

Since more students taking pre-calc were succeeding at Michigan Tech after taking ENG1001, in the Fall of 2004, ENG1001 became a required course for these students. Secondly, because both ENG1001 and ENG1101 covered some of the same introductory material, students commented that the course material was repetitive. To address this valid concern, the first year engineering program was modified to include ENG1100. With this new structure, students covered the ENG1101 material at a slower pace in two courses: ENG1001 and ENG1100. With this new structure, ENG1001 material retained the course coordination with Pre-Calculus and focused on engineering analysis. ENG1100 was developed to focus on problem solving skills.

When ENG1001 went from an elective to a required course, the class environment changed. Many factors contributed to this change. Students no longer self-selected to enroll in the course. When students are required to take a class, rather than are encouraged to take a class, some students bring a negative attitude to the classroom. Secondly, when students chose to enroll in ENG1001, the class size was approximately 35 students and three to four sections were taught each fall. Enrollment doubled when the class became required. Unfortunately, this meant that the class size increased to approximately 60 students due to classroom and instructor availability. Finally, the overall skill level of the students entering the program changed. Instead of most students lacking computer and technical skills, the opposite occurred. Many of the students had some computer experience and/or technical skills. Some changes were made to modify the course, but these changes were not enough to meet the needs of the more experienced student.

ENG1001/1100 Re-Structuring

In the summer of 2007, ENG1001/1100 were updated and modified to create a more challenging course sequence, along with retaining a relaxed pace for those students lacking computer and/or technical skills. Instead of just covering the ENG1101 material in a slightly different and slower pace, the courses were changed to include additional design and analytical material. To determine the direction the courses had to take, the course material was reviewed with three groups:

- Instructors who taught ENG1001/1100
- Instructors who taught ENG1101
- Instructors who taught ENG1001/1100 students in ENG1102

It was important to learn what was working in the classroom and what required change. It was also important to ensure that the skills learned in ENG1001/1100 paralleled those in ENG1101. Lastly, input from the instructors in the course following this sequence was needed to ensure the students were ready for ENG1102 or if the instructors had noticed skills that these students were lacking. Table 2 shows the modified course structures for ENG1001 and ENG1100. Some of the suggestions were:

- Emphasize calculations and analytical skills
- Cover engineering ethics in ENG1001
- Have student presentations and design project in ENG1100
- Maintain a focus on documentation and critical thinking

Table 2: ENG1001/1100 Course Structure

ENG1001		ENG1100	
Topic	Skills	Topic	Skills
Engineering Design	Memo Writing, Spreadsheet Calculations, Graphs, Tables, Statistical Calculations, Data Documentation	Spatial Visualization Skills	3-D Modeling Basics (UGNX), Spatial Visualization Exercises,
		Engineering Achievements	Technical Presentation
Engineering Ethics	Technical Poster Documentation, Web/Library Research Techniques, Peer Evaluation	Programming Basics	Microsoft Excel – Visual Basic
Sustainability in Engineering (Power Consumption, Ecological Footprint, Carbon Footprint)	Spreadsheet Analysis, Function Analysis, Data Documentation	Engineering Design Project	Projectile Motion (1-D & 2-D), Mathematical Model of Projectile Motion, Spreadsheet Analysis, Data Documentation, Design Project Report

ENG1001 Modifications

The emphasis in ENG1001 has changed from skill driven to emphasizing three subjects: Engineering Design, Engineering Ethics and Sustainability in Engineering. Within each subject module, many skills are taught where the activities emphasize calculations and documentation of various aspects of the subject.

ENG1001 begins with an engineering activity where student teams design a "Hole-In-One" for a miniature golf course. Within this module, students learn:

1. Teaming
2. Engineering communication skills (memos, e-mail protocol, figures, tables)
3. Units and unit conversions
4. Spreadsheet formula basics, graphing and tables
5. Basic statistics and quality control statistics

The “Hole-In-One” activity begins with students using graph paper to lay out a hole for a miniature golf course showing the trajectory to obtain a hole-in one.[5] The students must have the ball collide with either a wall or obstacle a minimum of eight times. The layout included a minimum of three obstacles that the ball must travel around. The hole configuration could have included bridges, water/sand hazards. The configuration could have any shape, but the angle at which the ball hits an obstacle is the angle it leaves. The student designs ranged from simple, right angle shapes to letters and numbers. The teams were extremely creative in their designs. After completing their designs on graph paper, they recorded grid lengths and angle measurements on a data table. They converted the grid measurements to length measurements using a scale of their choice. They documented their initial design in a memo to the instructor.

This was their initial exposure to memos as an engineering document and to unit conversions. In subsequent classes, the students were introduced to spreadsheets, basic spreadsheet formulas, tables and figures. Afterwards, they recorded their data in a properly labeled table and graphed their results. In conjunction with this assignment, student teams looked at the lengths of the different team designs. They calculated the mean, mode, median and standard deviation for the various configurations. In a detailed memo, they described their design, compared it to the other designs and analyzed the statistics of the different courses. Within this module, students learned how to use the z-tables to determine the number of "good" golf tees, clubs, and golf balls. Data from various manufacturers were used for the calculations.

After this module is completed, students learned about Engineering Ethics. This portion of the course is very similar to what has been traditionally covered in ENG1101 and ENG1100. The major alteration was that students learned how to create technical posters to communicate the aspects of an Engineering Ethics Case Study.[6] Each team created a poster to communicate their case study. The lecture material for the design of technical posters was modeled after materials from the Cain Project at Rice University.[6]

The student posters, overall, were of high quality. In class, 8 ½ x 11 color copies of the posters were evaluated by the students in each section. The students were asked to evaluate on three criteria: Layout, Readability, Communication of Topic and Eye-catching. The scale ranged from 1-5 (1 = poor/missing, 5 = excellent). The team with the highest score within a given section went to the competition. The students were excited to evaluate their peers and to see how their team's poster was received. They excelled at the critical review process. In fact, few teams evaluated their team's poster as the "best". The ones that did give their team the highest score were teams that had created a better poster than their peers. The instructor then selected one additional poster from his/her sections to go to the competition. It was difficult to select the poster for the competition because the students did an excellent job. Several students commented positively about the poster competition on their course evaluations. A typical comment was: "The group poster design project was excellent. I enjoyed."

The cost of printing the posters for all teams (36 teams) was expensive (approximate $20/poster). Therefore, the best poster from each section, along with an instructor choice (7 posters), were printed and evaluated by faculty in the College of Engineering. The poster competition occurred in a main lobby of the university. Many ENG1001 students went to see the posters, along with other students and faculty.

The competition judges consisted of four faculty from the College of Engineering representing Chemical Engineering, Mechanical Engineering, Civil and Environmental Engineering, and Electrical and Computer Engineering. The faculty judges were impressed with the students' ability to create a quality poster where the ethical issues were presented in a concise and logical format. The difference between the first and last place poster was very small. The team members that had "best" team poster received jump drives. The second place team received College of Engineering Nalgene water bottles. Each person participating in the competition received bonus points in the course. After the competition, the posters were displayed in the first year engineering classrooms.

The third module was designed to introduce students to the topic of sustainability in engineering design and implementation. The basics of the lectures were similar to the lectures in ENG1101 and ENG1001, Fall 2006. Within this module, spreadsheet basics and graphing were reviewed. Students completed spreadsheet calculations on their individual energy consumption within their residence hall room. This analysis was extended to investigate their impact on the environment through a simplified carbon consumption model. Students learned about the use of linear, power and exponential functions in engineering through analyzing global power consumption data. Within this analysis, students learned about different consumption models that are based on these function types.

ENG1100 Modifications

ENG1100 involved fewer changes than ENG1001. The major changes involved allowing more time for the computer intensive activities. Within this course, students developed their spatial visualization and programming skills and completed a technical presentation and semester design project.

The first half of the course focuses on helping the students develop spatial visualization skills through the use of a 3-D modeler (UGNX) and drawing/sketching exercises. The students use UGNX to model simple parts. They learn about geometric and dimensional constraints. They learn how to create an engineering drawing of their part using UGNX. Interspersed with these modeling exercises is hand sketching activities where students learn the basics of sketching a part, rotating it in 3-D space and creating the principle orthographic views of the part.

During this module, students learned about technical presentations and how they are similar/different to the technical posters they created in ENG1001. Each team researched and presented an engineering achievement that was listed on the Engineering Achievements Web Site.[8] Student presentations focused on history and cost/benefits of that achievement as well as how important the achievement is to different engineering majors. For example, air conditioning is used as a quality control device in the paper or computer industry and drastically changed the way buildings were designed by civil engineers. These presentations were spaced throughout the first half of the semester in ENG1100.

It was during this module that the semester design project was introduced. The design project consisted of designing a safe snowball launcher. Students developed a management plan and timeline for their project (using MS Visio and Word) and a general 3D concept model using UGNX. As a class, they analyzed the elasticity of the launcher cords to determine how the spring force in the cord is related to how much the cord is stretched. This activity served to review basic spreadsheet skills from ENG1001. At this point in ENG1100, students were introduced to functions using Visual Basic (VBA) Programming. To add to their spreadsheet skills, the students also developed a VBA function to display their elasticity data.

During the next step in their design project, students built on their knowledge of spreadsheets through learning about programming using Visual Basic in Microsoft Excel. VBA was then used by the students to create a mathematical model of their proposed launcher. These models calculated the force and angle necessary to launch the snowball to reach a target 30 meters away. The math model calculations used in their model come from the 2D motion material covered in class and also parallels material covered in their physics classes. Students validated their model predictions and reported on their results in a final technical report.

Anecdotal Evidence of Success

Because the course modifications have just been completed, there is little assessment data that has been collected. The instructors have noticed that the students were more active in class.

The Ethics Poster competition was one of the best received changes implemented (See comment above). Students really applied themselves to the creation of the posters. From student comments, this was primarily due to outside evaluators. The students looked forward to being judged by faculty who would be teaching them their upper division courses.

Throughout the semester, students were required to interpret charts, graphs and data. There was a significant increase in their documentation from the beginning of the semester to the end of the semester. For example, one student team met with their instructor seven times to write a memo where they actually discussed critically their miniature golf course "Hole-In-One". It was extremely difficult to convince the team members that they needed to describe within the memo what they designed and accomplished on the assignment. This team showed significant improvement when they submitted a later example regarding their ethics case study poster. In this memo, they outlined and described their case study in a concise and organized manner. Many students commented that they learned a great deal during the spreadsheet portion of the course where they learned how to not only create graphs, but also interpret them. An typical student comment was: "I liked using EXCEL and doing the math in the problem solving method."

Students appreciated the addition of real world examples into the statistical analysis of the course. In conjunction with learning functions and formulas on spreadsheets, students learned how to use z-tables and what a normal distribution was. One student commented: "I liked how normal distributions were taught using real life examples to build into the problem to make it easier to understand."

Conclusions

The restructuring of ENG1001/1100 has created a more challenging class for all students enrolled in the course. Through more class applications and design activities, students have learned to apply more of the skills presented in the class. Also, the use of activities to improve the class did not adversely affect the students who lacked computer skills.

In summary, ENG1001/1100 have been updated to emphasize student analyses and computations. Throughout the courses, students completed calculations, analyzed data and documented their work. These courses will continue to be improved as needed and as student skills change. Data will be collected in Fall 2008 when the students complete ENG1102 to determine the success of these changes.

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