

## **Using Engineering Courses to Improve Pre-Calculus Students' Success**

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### **Abstract**

Many engineering students are not ready to take Calculus their first semester at Michigan Tech and are unable to participate in the First Year Engineering program at that time. To prepare them for their first year experience and to enable them to take an "engineering" course during their first semester, an introductory engineering class, Engineering and Science Applications in Pre-Calculus (ENG1001) was pilot tested Spring 2001 and refined and expanded in Fall 2001 and Fall 2002. Because students are enrolled in Pre-Calculus and ENG1001 at the same time, the ENG1001 course material parallels the topics that are being covered in Pre-Calculus. In addition to coupling ENG1001 with Pre-Calculus, another objective of this course is to prepare the students to succeed in their future engineering courses. Students work in three-person teams on class assignments, lab reports, homework assignments, technical presentations and a design project. Topics are introduced that will be used and expanded upon in the first-year engineering program. Hands-on experiments are used to illustrate engineering principles and to obtain data for analysis. Students solve algebraic and trigonometric engineering equations using a spreadsheet and they receive instruction on how to logically outline and solve engineering problems using a five step method (Read, Find, Known, Solve and Check) as outlined in their Pre-Calculus text. Within one semester, these students make the transition from not knowing how to even start an engineering problem to being able to adequately communicate a solution process. This paper outlines some of the projects students completed and how students applied engineering tools and mathematical concepts to their solution. In addition, it shows how student performance was enhanced in Pre-Calculus and Calculus as well as in their subsequent engineering course.

## Background - First Year Engineering at MTU

In Fall 2000, Michigan Tech started a First Year Engineering program<sup>1</sup>. This program consists of several courses that must be taken co-currently: Calculus, Engineering and Physics (see Table 1). This allows the instructors of these first year courses to integrate what students are learning in math, science, and engineering wherever feasible. After the second semester, MTU students are ready to begin taking courses directly related to their engineering program of choice.

**Table 1:** Typical First Year Engineering Courses for Students that are Calculus Ready

First Semester	Cr	Second Semester	Cr
Calculus I*	4-5	Calculus II*	4
Engineering I*	3	Engineering II*	3
Physics Lab I*	1	Physics I*	3
Chemistry I	4	Other	1-4
General Education	3	General Education	4

\* Co-requisite courses for the First Year Engineering Program

The Calculus co-requisite for the First Year Engineering courses requires students that are not Calculus ready to find other courses to fill their schedule. This affects approximately one-quarter of the first year engineering students<sup>2</sup>. To help these students succeed in future classes and introduce them to engineering, Excelling in Science and Engineering Learning (ExSEL) program is available. ExSEL provides additional help to students via mentoring, tutoring, and counseling, which strengthens their academic performance. It is supported by Michigan Department of Career Development, King-ChávezParks Initiative and Michigan Technological University, College of Engineering.

Two classes are part of the ExSEL program: Engineering and Science Applications in Pre-Calculus<sup>2</sup> (ENG1001) and Frameworks for Success. ENG1001 helps students become more proficient in Pre-Calculus as well as prepares them for their engineering classes. Frameworks for Success helps students with time management, study skills, and general coping skills needed by first year students. Students choosing to participate in the ExSEL program, have a first semester schedule as found in Table 2. For students starting in Pre-Calculus, it takes 3 semesters before they are ready to begin taking courses directly related to their engineering major. While students take two classes as part of the ExSEL program, ENG1001 is the focus of this paper.

**Table 2:** Typical Pre-Calculus Engineering Student Courses at MTU

First Semester	Cr	Second Semester	Cr	Third Semester	Cr
Pre-Calculus*	5	Calculus I**	4	Calculus II**	4
Engineering & Sci Apps*	2	Engineering I**	3	Engineering II**	3
Frameworks for Success*	1	Physics Lab I**	1	Physics I**	3
Prep-Chemistry	4	Chemistry I	4	Other	1-4
General Education	3	General Education	3	General Education	4

\* ExSEL Program Courses

\*\* Co-requisite courses for the First Year Engineering Program

## Engineering & Science Applications in Pre-Calculus - ENG1001

ENG1001 was pilot tested Spring 2001 and refined and expanded in Fall 2001 and Fall 2002. Some of the improvements that were made after the pilot course were:

- Class meeting twice a week instead of once a week,
- Additional engineering topics,
- Hands-on engineering and teaming activities,
- Tutoring one hour a week,
- Data collection and lab reports, and,
- Semester design project.

Pre-Calculus is a co-requisite of ENG1001, therefore the ENG1001 course material parallels the Pre-Calculus material. The Pre-Calculus topics are applied to engineering problems allowing students to practice real-world applications of the math tool they are learning. In addition to coupling ENG1001 with Pre-Calculus, another objective of this course is to prepare the students to succeed in their future engineering courses.

The goals of ENG1001 are as follows:

- To develop proficiency in problem organization and problem solving,
- To develop proficiency in the use of computers in solving engineering problems,
- To improve engineering communication skills, and,
- To understand the integration of Mathematics, Engineering and Science.

The course meets twice a week for 1.5 hours in a classroom with computers for each team of 3 students (see Figure 1). These teams are utilized for in-class as well as out of class activities and homework. During class, teams participate in hands-on activities, work on the computer and solve engineering problems on paper. In addition, teams work together on presentations, data collection, lab reports and a semester design project. Student teams also meet with a tutor one hour a week to go over any homework or subject questions they have.



**Figure 1:** Students work and giving presentations in Computer Aided Classroom.

## Tools, Topics and Activities

As shown above, students work in a high-tech computer classroom. This allows students to have engineering tools at their fingertips. Problem organization on paper and using spreadsheets were the primary tools focused on in ENG1001. Problem organization gets students in the habit of setting up large problems so a co-worker can check their work. Students learn a five-step problem solving method<sup>3</sup>, taken from their Pre-Calculus text, to help with the organization:

- **Read** – Summarize problem statement
- **Find** – List what is asked for
- **Known** – List what is given or assumed
- **Solve** – Show a step by step solution
- **Check** – Check work mathematically and logically

Students incorporate this method into solving problems using spreadsheets. The aspects of spreadsheets learned are: labeling data, performing calculations using relative and absolute cell addressing, calculating using internal spreadsheet functions (i.e., sin, cos, pi, slope, intercept), graphing several sets of data on one graph, changing axis scales, labeling and titling graphs, printing data and printing internal cell equations.

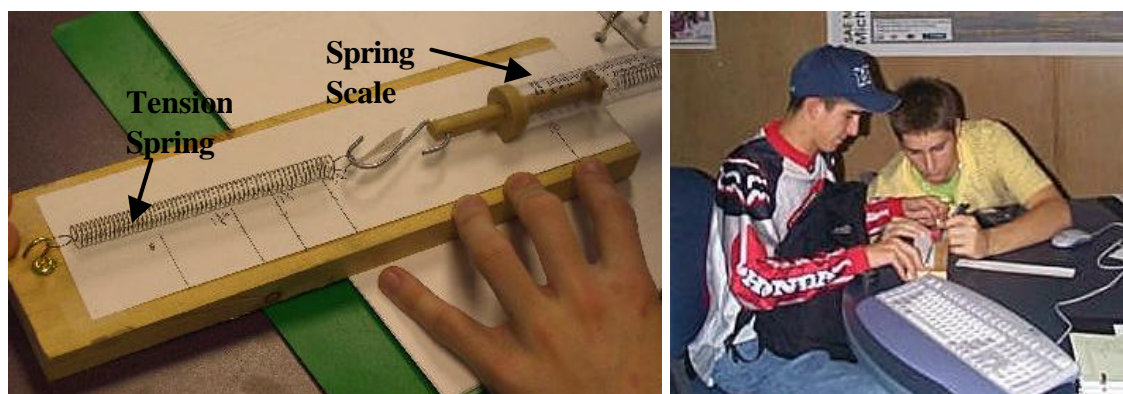
ENG1001 applies Pre-Calculus methods to engineering topics using these engineering tools. For example, while students are learning about exponential functions in Pre-Calculus, ENG1001 investigates growth and decay of bacteria and materials and increase and decrease of atmospheric pressure or medication in the bloodstream. In addition, these problems are graphed by hand on semi-log paper as well as graphed using spreadsheets. As part of this exercise, students learn how to change the axis scale on the spreadsheet. Some additional topics that are covered in the course include:

- Unit Conversions
- Collecting, Graphing, Interpreting and Modeling Data
- Creating & Giving Technical Presentations
- Writing Reports
- Angles, Trig Functions, and Circular and Projectile Motion

Since most engineers work in teams, there are several activities to get the students working together while completing engineering activities. These activities include:

- Distributed Loads - Save the Grape
- Spring Analysis - Calculate Constants
- Investigating Mineral Properties - Engineering Materials
- Structural Support - Tower of Straws
- Engineering in the World Around Us - Scavenger Hunt

To give an idea of what these activities entail, the Spring Analysis activity will be described. For the spring analysis, students are given a tension spring and spring scale. Students collect force and change in spring length data (see Figure 2) and graph it on a spreadsheet. Then students calculate the spring constant by determining the slope and intercept of the data. Since each team works with a different spring, the class data are compared to see which spring is stiffer or softer. Student teams also incorporate and interpret their data in a lab report.



**Figure 2:** Spring Analysis

## Design Project

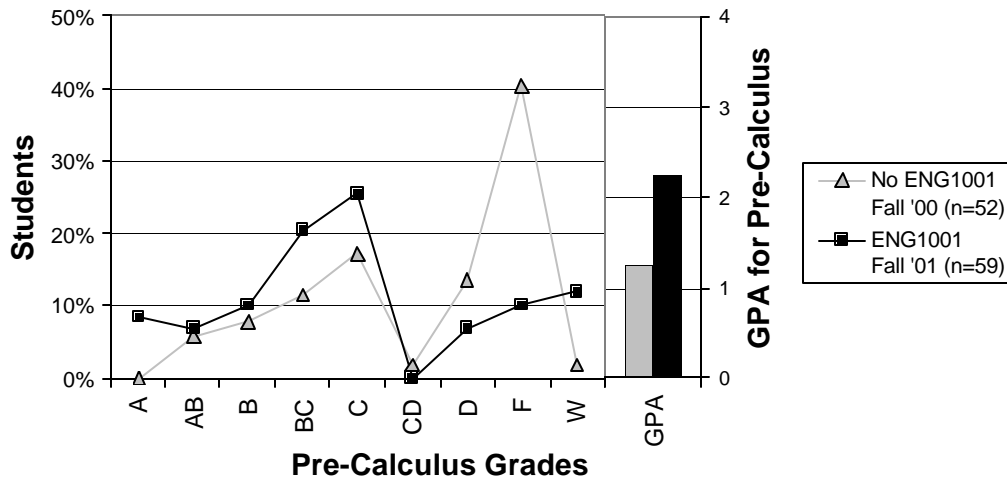
For the semester design project, students designed and built a ping-pong ball launcher that was safe and easy to operate. Students brought their launcher to class for testing and collecting data. The data were used in a projectile motion analysis using trigonometric functions and spreadsheets. Teams gave mini-presentations on how to operate their launcher. In addition, teams submitted a final report about their launcher. This report included a description on how to build their launcher, the theory of operation and the interpretation of their spreadsheet analysis.

## Pre-Calculus Grade Results

ENG1001 provides Pre-Calculus students with an engineering class their first semester at Michigan Tech. This course compliments students' math course hoping to improve students' success and retention. To determine the impact of ENG1001 on Pre-Calculus grades, students with similar math skill levels are compared. The two skill levels are:

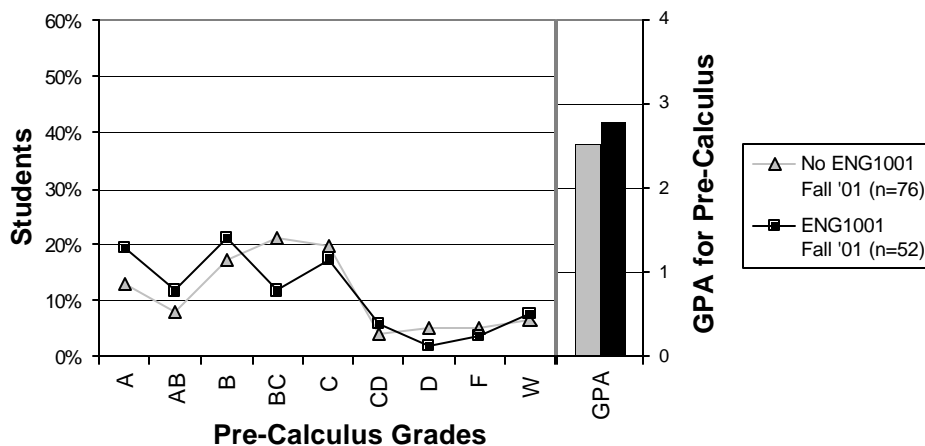
- Math ACT of 19-22 – required to take ENG1001 in the Fall 2001
- Math ACT of 23-25 – not required to take ENG1001 in the Fall 2001

ENG1001 was required for students with a math ACT score of 19-22. Therefore, Fall 2000 data (when ENG1001 was not offered) is used as a control group. Figure 3 compares student data from Fall 2000 (52 students) and Fall 2001 (59 students). This figure shows that there are more passing grades (A-C) and less failing grades (CD – F) in Pre-Calculus for students taking ENG1001. This represents an increase in the Pre-Calculus GPA of 0.98 on a 4.0 scale. In addition, there are no A's and twice as many F's and W's, combined, in the non-ENG1001 group.



**Figure 3:** Fall 2000 and 2001 Pre-Calculus Grades of Students with math ACT 19-22. (W = withdraw from course, GPA = Average Pre-Calculus GPA for group of students)

Figure 4 compares students with math ACT scores of 23-25 for Fall 2001. There were 52 students taking ENG1001 and 76 students not taking ENG1001. The data show that students taking ENG1001 received more A's, AB's and B's and less BC's. Grades of C and below stayed about the same. These differences represent an increase in the Pre-Calculus class GPA of 0.25 on a 4.0 scale.



**Figure 4:** Fall 2001 Pre-Calculus Grades of Students with math ACT 23-25. (W = withdraw from course, GPA = Average Pre-Calculus GPA for group of students)

The following semester, students' grades in their next math (Calculus) and engineering (ENG1101) class appeared to be relatively the same. There were only two significant grade differences to report; students who took ENG1001 received more A's and AB's in ENG1101. There were 20% more A's and AB's for students with a math of ACT 19-22. There were 15% more A's and 7% more AB's for student with a math ACT of 23-25. In addition to the grade increases, a greater percent of students continued on to their next math and engineering class, (see Table 3). For students in the lower ACT range, approximately 10% more students continued

on to Calculus and ENG1101. For students in the higher ACT range, there was a 2% decrease in students taking Calculus, while there was a 7% increase in students taking the engineering class.

**Table 3:** Percent of initial students that continued on to the next math and engineering class.

	ACT 19-22		ACT 23-25	
	No ENG1001 – '00	ENG1001 – '01	No ENG1001 – '01	ENG1001 – '01
Calculus	48%	58%	79%	77%
ENG1101	56%	69%	74%	81%
Initial number of Students	52	59	76	52

## Survey Results

For the pilot study, surveys were sent out one semester after students completed ENG1001. Students were asked to rank each topic in relation to how ENG1001 helped prepare them for their next semester's engineering class (ENG1101). The ranking was set as follows: 1=no help; 2=slight help; 3=some help; 4=adequate/useful; 5=excellent preparation.

Of the students surveyed, 50% responded. Most topics were ranked as a 4.0. The following topics were ranked over 4.5 and represent the most helpful topics to the students:

- The application of unit conversions in engineering problems
- The use of spreadsheets to solve engineering problems
- The use of relative and absolute addressing in spreadsheets
- Graphing using spreadsheets

Students' comments about the course were also collected with the survey. Some of those comments are included below.

"At the time, I didn't appreciate the class, but after being in ENG1101, I am very thankful for everything I learned in ENG1001. I don't think I could've been as successful in ENG1101, without it."

"The class made me more confident in my ability to solve story problems, and improved my ability to solve them."

"I feel that all the computer modules from the ENG1001 gave me a good head start."

Students had a positive response to the class. In an unrelated survey during Spring 2002, students were asked what their favorite thing was the previous semester. Of the students that had ENG1001, 30% (27 of 89 students) included ENG1001 in their response.

## Conclusions

Students that are not ready to start the First Year Engineering program at Michigan Tech have the opportunity to take Engineering and Science Applications in Pre-Calculus. This class

provides students with an engineering class that improves their Pre-Calculus knowledge as well as their computer and engineering skills. Students' Pre-Calculus grades improved, students received more A's and AB's in their next engineering class, and a greater percentage of students successfully progressed to Calculus. The students self-reported that they felt that the class prepared them well for future class and gave them a foundation necessary to succeed.

## **Acknowledgement**

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## **References**

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