The Untapped Pipeline and the Math Myth

Amy J. Moll, Patricia A. Pyke, and John F. Gardner

College of Engineering
Boise State University

Introduction

This paper is meant to initiate a discussion instead of proposing a solution. It represents the authors’ discussions over the past few years on how to increase enrollment in engineering programs as well as attract more women and minorities to study engineering. The authors hope that these ideas will prompt discussion among engineering educators on how to interest more students in studying engineering and how to interest more women in the field.

In the last 20 years, in the United States, the overall enrollment in engineering has decreased. The percentage of women studying engineering has remained nearly stagnant, despite many bridge programs, summer camps, workshops for young women.

The Math Myths

Many ideas have been put forth as to why engineering enrollment is declining and why engineering does not attract more women: the nerdy image of engineers, the perception that engineers do not help people, and a lack of an understanding by the general public of what engineers do. In this paper, we would like to discuss what we will call math-myths. If you ask engineers why they entered engineering they will often tell you that they were good at math and science in high school. High school counselors, high school math and science teachers and college engineering professors will often tell a student, “You HAVE TO be superior at math to be an engineer.” This statement also implies that you have to take advanced placement math and AP Calculus in high school to succeed in an engineering college. Are these statements really true? And what impact do they have on the student’s career choice?

The authors suggest that it is a myth that students HAVE TO be excellent at math to be an engineer. Clearly math is a very important tool for engineers. All engineers must have some level of competency at math. However, once students are no longer taking classes at a university, the amount of math used in engineering positions varies widely. For many B.S. level engineers in the workplace, advanced math is not a regularly used skill. Also, most engineers do not go on to graduate school, where higher level math may be required. For those who classify themselves as employed engineers in the United States, 57% list a bachelor’s degree as the highest degree obtained.[1] Again this is not to imply that math is unnecessary. However, an engineer can succeed by nurturing a tolerance for math not necessarily a passion for math. Other skills, such as problem solving, creativity, ingenuity, and good communication skills may be just as essential to an engineer’s success as is math.
The second myth – that students must be advanced placed – is even more damaging. Across the nation, students are “tracked” into math courses as early as 5th or 6th grade. At the tender age of 11 or 12, many students get derailed off the math fast-track. Once off track, it is extremely difficult, if not impossible, to return. The reasons capable students leave the accelerated math track are many and include interests in other subjects or sports, family difficulties such as divorce, illness or relocation, developmental variations, peer pressure, or unreliable advice from school staff. In addition rural schools and the poorer school districts often do not offer an advanced math track. And, even in this new millennium, cultural and institutional biases still result in many girls feeling unwelcome in advanced math classes. Hence, based on a decision or a circumstance that could have occurred as young as 11 years of age, the student is no longer considered a good candidate for studying engineering.

Although progress has been made for girls and women in the last 15 years, in high school, girls are less likely to take AP Calculus. Boys taking the AP Calculus AB test outnumbered girls, 52% to 48% in 2004. The disparity grows for Calculus BC. Only 40% of the examinees for the exam in 2004 were female.[2] The Scholastic Assessment Test scores for college bound seniors consistently shows that females score lower than males in the mathematical portion of the exam as shown in Figure 1. [3]

![SAT Score Avgs for College Bound Seniors](image)

**Figure 1:** SAT score averages for college-bound seniors, by sex: 1966-67 to 2002-03. [3]
In addition to gender, other factors strongly affect math scores on the SAT. African-Americans, Hispanics, Latinos, Mexican Americans, Puerto Rican and American Indians all score significantly lower than Whites and Asian Americans on the SAT math test. [3] Socio-economic status is also a factor as the average score on the math portion of the SAT increases with increasing family income. [3]

Many well-meaning engineering professors who perpetuate the math myths will protest that they only want to attract the brightest students with the best chance of succeeding in engineering. Students without the proper preparation will not do as well and have a higher rate of dropping out than the students who have done well in their studies – particularly math. We have several counter arguments: First of all, more students need to consider engineering an option so more will begin the program. Eliminating students at age 11 is no way to increase enrollments. Setting the entry criteria in way that only encourages the very top students eliminates a large population who could contribute great creativity and energy to the field. Second, a B.S. in engineering provides a solid foundation from which to pursue many other professions. For example, patent attorneys must have engineering, science or technology degrees[4] and biomedical engineers have the highest rate of acceptance to medical school of any major.[5] Finally, an engineering degree results in a well-informed citizen with the skills to make informed decisions about many of the complex problems present in today’s society. Even if these students do not continue in engineering throughout their career, they will be better prepared for whatever they do. Technology literacy is important in almost every career.

Is it necessary to select only the student with the top math scores to enroll in engineering? Can we afford to eliminate capable women and other under-represented groups because of their reluctance or lack of opportunity to take advanced math in high school or because they consistently score lower than white males on standardized math exams? Can an engineering program provide support for those under-prepared in math, allowing them to be successful in an engineering degree? We propose that bridge programs can provide academic support while the students complete college algebra and pre-calculus and can result in a student who is equipped to succeed in the regular engineering curriculum.

Experiences at Boise State University

Boise State University is a metropolitan university with more than 18,000 students enrolling every semester. The College of Engineering was formed in 1997 and offers B.S. M.S, and M. Eng. Degrees in Electrical Engineering, Civil Engineering, Computer Science, Mechanical Engineering and Materials Science & Engineering. A large fraction of the students at Boise State (46%) are non-traditional students defined as those older than 24 years of age. Because of this and because of the general population that Boise State serves, many of our engineering students begin their studies under-prepared in math and often require 2 or even 3 semesters of math before they are ready for Calculus. In addition, many of our students struggle through the math sequence and often take Calculus I and Calculus II two or three times before earning a passing grade. Yet many of these students succeed at mastering math concepts, applying those concepts to
engineering courses, and achieving graduation. A snapshot of the 2003 graduating class in Mechanical Engineering is a good indicator. Of the 37 students that graduated, only 8 students started their college career in Calculus I. The majority of the students, 23 out of 37, required one or two preparatory math courses, Intermediate Algebra and Pre-Calculus. Three of these students began their college studies in developmental algebra, a non-credit bearing course. Even though many students arrived at Boise State under-prepared in Math, our graduating students have one of the highest pass rates on the Fundamentals of Engineering exam in the nation. The individual stories of our students bear more witness to the fact that their success is NOT dependent on where they started in math. One student who came from a small rural high school where she did not have access to a Calculus course, began her college career in Pre-Calculus. She graduated Magna Cum Laude, was awarded a National Science Foundation graduate fellowship, and is currently pursuing a PhD in Mechanical Engineering.

The College of Engineering at Boise State is developing ways to support the engineering student who is under-prepared in math. With a grant from the Hewlett Foundation, a new version of the required Introduction to Engineering course has been created. At Boise State, Introduction to Engineering is a module based course, intended to introduce the student to the profession of engineering and provide hands-on activities that reinforce the material learned in Calculus and Chemistry as well as provide an introduction to the professional skills required of engineers. The prerequisite for this class is Pre-Calculus or placement into Calculus.

A new class, Introducing Engineering, was designed for students enrolled in Pre-Calculus and substitutes for the Introduction to Engineering requirement. The course follows the same schedule and completes the same modules as the regular course. Additional class time is required in order to provide extra support for the math portions of the modules. The syllabus and schedule of modules is provided below. The course was offered for the first time in the fall semester, 2004. The students will be tracked over the next two years to see how their retention and success compares to the other students enrolled in engineering programs.

**ENGR 197 Introducing Engineering, Syllabus**

**ENGR 197 INTRODUCING ENGINEERING (1-6-3)(F/S).** The engineering profession and professional organizations, application of computer software to solving engineering problems, and introduction to the design process. Student design projects emphasize critical thinking and teamwork, and require oral and written presentations.

Course Web Site:  blackboard.boisestate.edu  
Schedule:  MWF 8:40-10:30 am  
FRIDAY, 12:40-1:30 pm  MEC 106

Detailed Course Description:  
ENGR 197 is an introduction to the profession of Engineering. Intended to give the students an idea of the type of work they will encounter as engineers. The course is also intended to provide engineering experiences while the majority of your coursework is focused on math, physics and chemistry. Our intent is that the course allows the student to experience the following:
The creativity and fun of the engineering profession
An introduction to the engineering profession through a series of lectures and hands-on activities that allow the students to gain insight into the activities of a professional engineer.
An introduction to specific computer based tools and techniques that will be useful in engineering problem solving and communication.
An opportunity to develop:
- An ability to design a system, component or process to meet desired needs
- An ability to function on multi-disciplinary teams
- An ability to identify, formulate and solve engineering problems
- An understanding of professional and ethical responsibility
- An ability to communicate effectively
- A recognition of the need for, and an ability to engage in life-long learning
- A knowledge of contemporary issues

Special Note
This course is a special offering of ENGR 120 and we intend to offer extra support to the students, particularly for MATH 147.

Course Objectives:
At the end of the course, the student will be able to:
- Utilize knowledge from calculus, chemistry and physics coursework to describe and analyze simple engineering problems.
- Use Excel spreadsheets for analyzing and graphing data
- Use Powerpoint for technical presentations
- Demonstrate critical thinking and problem solving strategies important to all engineering disciplines.

Learning Community
Many of you are part of a learning community and you will be in the same section of MATH147, COMM101, and ENGL101. The intent is to help build a group that can study together and work together towards success. Research has shown that students learn and retain more when they study in groups.

Grading:

<table>
<thead>
<tr>
<th>Grading</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written Reports</td>
<td>25%</td>
</tr>
<tr>
<td>Oral Reports</td>
<td>25%</td>
</tr>
<tr>
<td>Short Assignments</td>
<td>25%</td>
</tr>
<tr>
<td>Attendance</td>
<td>25%</td>
</tr>
</tbody>
</table>

Grading:
A = 90-100
B = 80-90
C = 70-80
D = 60-70
F < 60

Attendance
Attendance is critical for this class in all lab classes and at the lectures.
An unexcused absence will result in a deduction of 5 points from your final grade.
Two unexcused absences will result in a deduction of 10 points from your final grade.
If you have more than two unexcused absences, you will fail the course.
In the case of an unexpected event, notify your instructor, by email, as soon as possible.

Class Policies:
It is assumed that all students are familiar with BSU's "Student Code of Conduct" and agree to abide by its principles. All students should familiarize themselves with this document that can be found on the web:
http://ww2.boisestate.edu/studentconduct
Any incidence of academic dishonesty (e.g. cheating, plagiarism, theft) or un-collegial or illegal activities will not be tolerated and will be addressed within the procedures outlined in BSU's code of conduct.
The Introducing Engineering course is the beginning of an effort to create a foundation year that will increase the success rate of students who are under-prepared in Math. This year will consist of a foundational course in Chemistry, a foundational course in Physics, core courses in English and Communication and University 101. University 101 is a course which aids the student in the transition to college by teaching time management and study skills. The core of the foundation year is the math preparatory courses – College Algebra and PreCalculus. As part of the foundation year, additional math support is provided to the student through Supplement Instruction.[6] Additional ideas to increase retention of these students in engineering include forming learning communities.
where a cohort of students are enrolled in the same section of all their courses, the
development of a Residential College for engineering students, and creating research
opportunities for lower division students.

Conclusion

Hopefully this paper will stimulate discussions in the engineering education community
of alternative ways to attract more students, more women and more under-represented
groups to the field. As the program at Boise State progresses, the impact of new
programs supporting students that are under-prepared in math will be reported as well as
the impact on recruiting and retention on engineering students.

References


Examination for Registration to Practice in Patent Cases Before the United States Patent and
p. 4.

[5] Association of American Medical Colleges, “Medical School Admissions Requirements,” 2002-
2003.

Instruction Model to Improve Student Success,” Proceedings of the 2005 American Society for
Engineering Education Annual Conference & Exposition, June 2005, Portland, OR.