Improving the Educational Experience of STEM Majors
K-12 Preparation and College Experience

by Cindy P. Veenstra

"The keys to economic growth are education and innovation." —James Duderstadt[1]

Research indicates a serious shortage of U.S. engineers and scientists. As a result, there is a significant research effort to increase the number of science, technology, engineering and math (STEM) majors in U.S. colleges and universities. This article will discuss the reasons for the shortage and current efforts to improve the STEM pipeline both in the K-12 school systems and in universities. It will conclude ideas from my recent doctorate research, which suggests engineering majors have different needs than other STEM majors in their freshman year of college.

Understanding the shortage of STEM majors

U.S. educators recognize the need for more STEM majors to fill the demand for engineers and scientists in both industry and research. There are a number of reasons for the gap between the demand for engineers and scientists and the graduation of STEM majors from colleges, including:

- The demand for engineers and scientists is increasing. The increase is expected to be 4% per year for engineers.[2]
- Baby boomer engineers and scientists are retiring.[3]
- A lower percentage of high school students are interested in engineering (approximately 5%).[4]
- There's a low college graduation rate of STEM students. The national graduation rate of engineers is about 55%.[5]

With a shortage of bachelor-degreed graduates in the STEM majors, a shortage of doctorates in the STEM disciplines will result. This might lead to less innovation in research, which can contribute to less global competitive advantage.

Women are entering the STEM majors in college at a much lower rate than men. Only 17% of the undergraduates in engineering are women while the percentage of bachelor-degreed engineers who are women is nationally about 20%.[6,7] Yet in some engineering fields, there is a high percentage of female graduates, including 43% of the

environmental engineering degrees and 42% of the biomedical engineering degrees.[8] Research indicates the issue is not academic preparation but rather career choice. More female students tend to be drawn to engineering majors that will enable them to help people in society. With women constituting half of the population, increased participation in the STEM disciplines would significantly improve the outlook for U.S. innovation in the sciences and engineering.

In addition, minorities are under-represented in the STEM disciplines. Blacks and Hispanics constitute 25% of the U.S. population, yet they account for only 11% of the engineering graduates.[9]

K-12 school system solutions

For students in the K-12 school systems to become successful in a STEM career, two components are needed: an interest in the field and significant preparation in math and science courses in high school. Both interest and preparation are influenced by experiences in middle school.

Turning this shortage around will take time, and preparation in math and science in middle school and high school is key to changing this trend. A report this year by the National Mathematics Advisory Panel recommends that all students should be competent in algebra.[10] ACT has established college readiness benchmarks based on the ACT Math and ACT Science scores. An ACT Math score of 22 indicates a readiness for the first course in college math, and an ACT Science score of 24 indicates a readiness for freshman science.

Of the 2005 high school graduates who took the ACT test, only 41% achieved the math readiness benchmark. The good news is that 70% of the students who started college in a science field and had met the science readiness benchmark graduated. If students are not enrolling in geometry, trigonometry and calculus in high school, they will be less prepared to compete in the STEM major courses in college. ACT research indicates high school physics is a key science course for raising college readiness in scientific thinking.[11]

Research shows that teacher preparation also is important. The National Academy of Sciences has recommended the need for more math and science teachers as well as more scholarships to encourage college students to consider a career as a math or science teacher. In addition, the academy has been recommended that teachers be provided with more training to effectively teach math and science courses.[12] As more

research becomes available, teaching techniques that help students learn math and science concepts will become more available.

The Baldrige quality model has worked for many school systems. Several have received the Malcolm Baldrige National Quality Award. ASQ's Quality Press has published *Transformation to Performance Excellence*, which provides interviews with the leaders of school systems that have received the Baldrige award.[13] Included in the interviews is advice on improving a school system's processes to enable all students to achieve academically at a higher level. The academic achievement of all students is needed in the new global competitive environment, and it is a basis for preparing potential STEM students for college.

Perhaps two areas have been overlooked in the literature for their effectiveness:

1. There is a need for more science and engineering based extracurricular activities for middle school and high school students to provide students hands-on experience and to excite them about the STEM fields. Some current examples are Science Olympiad, FIRST and Odyssey of the Mind.
2. It is important to provide parents with information on STEM careers and the need for math and science preparation in high school.

Higher education efforts

More research is being conducted, and research universities are establishing engineering education departments that conduct research for the STEM pipeline in the K-12 school systems. Purdue University, Virginia Tech, Colorado School of Mines, Arizona State University, Tufts University and the University of Virginia conduct research in K-12 outreach.[14] Included in these outreach activities are partnerships or workshops with teachers and opportunities to mentor high school students toward STEM careers.

Massachusetts Institute of Technology has partnered with WGBH-TV Boston to create the Design Squad TV show (see http://pbskids.org/designsquad/).[15] The show exposes 9 to 12-year-old students to engineering concepts and the excitement of an engineering or science career. It has been very successful, because it can reach more students by TV than universities can reach with their outreach programs. Both approaches are needed and complement each other.

University of Michigan research

As part of my doctorate research, I modeled freshman retention of both engineering and nonengineering STEM majors—science, math and technology. The freshman year was chosen because the highest attrition of STEM majors occurs between the freshman and sophomore year. Consistent with other engineering retention studies, a strong academic high school record (as measured by a student's high school GPA and rank) and an excellent knowledge of calculus and science (as measured by the ACT Math and Science scores) was predictive of academic success in the first year of college. In addition, confidence in math skills was also a significant variable to predict academic success of engineering students.

Interestingly, the model for freshman academic success is not the same for all STEM majors. In this study, while math knowledge and confidence in math skills were significant predictors for academic success, overall academic knowledge and overall intellectual confidence were significant predictors for the nonengineering STEM majors. This difference appears be due to engineering students taking more courses in their first year that are dependent on a strong math background.[16] This suggests different strategies for student success might be needed for different STEM majors.

More research, effort needed

There are many ways to improve the educational experience of STEM students. Academic preparation in high school, confidence in math and science abilities, and establishing an interest in science, math, technology and engineering through extracurricular activities in the K-12 school system are important. We cannot underestimate the importance of students taking three to four high school courses each in math and science for academic success in the STEM majors in college. We must show middle school and high school students the excitement of careers in the sciences and engineering. We must encourage girls and minorities to consider these careers—careers that might be considered nontraditional.

More new teachers will be needed in these fields in the near future. More research in how to teach math and science is also needed. In some cases, school systems are challenged by their efforts to raise the academic achievement of their students. The K-12 school systems using systems thinking consistent with the Baldrige quality model have had good success.

At the higher education level, more research is being conducted to improve student success. More effort is needed to improve the graduation rate through student

success programs that help students achieve academically. With these efforts, meeting the needs of more scientists and engineers will be accomplished.

References

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