The Role of Engineering Design Graphics has in K-12 Outreach

Aaron C. Clark
Graphic Communications Program
North Carolina State University, Raleigh, NC 27695-7801

Alice Y. Scales
Graphic Communications Program
North Carolina State University, Raleigh, NC 27695-7801

ABSTRACT- *For years, professionals in Engineering Education have struggled with the need to recruit more and better prepared students into fields related to engineering. Recently, there has been a push to develop pre-engineering programs for public secondary education programs that will help with recruitment and provide high school students with the needed background for success as an engineering student. Many disciplines have initiatives related to this new trend in public education, but with limited success, as it is new to states. Considering this new era of pre-engineering education and students' need for a foundation in areas related to engineering before they come to college, professionals in our field Should ask the following questions: What is the role of engineering design graphics in this new curricula approach? How is engineering graphics viewed by those organizations that are developing materials in pre-engineering and what are their expected outcomes? Is there research that supports our task as engineering graphics educators to become involved in this new curricula initiative in secondary education? How will this national effort affect the students we will have in our classes? Although many of these questions can only be answered in theoretical terms, a historical perspective, and identifying what professionals in our field and others are doing, may help the engineering graphics community decide the position we should take in pre-engineering education.*

This paper is designed to give the reader insight into this new pre-engineering initiative from both secondary and post-secondary viewpoints. Information about the kinds of initiatives to meet this pre-engineering curricula need currently underway at the national level will be presented. The conclusions will provide suggestions and strategies for the promotion of engineering design graphics in the k-12 outreach for engineering education.

I. PRE-ENGINEERING EDUCATION

> "Engineers like to solve problems. If there are no problems handily available, they will create their own problems." (Scott Adams, 1957)

Technology and engineering has played major roles in fostering the US economy. Many companies consider engineering the "driving-force" behind their success and their growth. They also feel it will help them remain competitive in the global market place in the coming years. Considering this, many professionals in the fields of education and engineering think it is imperative that everyone in our society be technologically competent and have the ability to create, use, manage, and assess technology, including students in our k-12 schools. Statements like the ones above are being made throughout the country by business and educational leaders, and, at the same time, elementary and secondary students' interest in technology and engineering disciplines continue to weaken. Although it is believed by many professionals in education that students have a deep interest in technologies that they deal with day-to-day, few possess the background and knowledge to understand the underlying principles associated with these everyday technologies. Some states, federal agencies, and professional organizations have started to make an effort in eliminating these deficiencies, but more is needed from a variety of disciplines in both public and private sectors[1].

Engineers and technologists are important and vital to the profitability of the US economy. The U.S. Department of Labor statistics reveal that there needs to be at least a 20% increase in engineers over the next decade[2] and that individuals majoring in engineering education "peaked" in the early 1980's, with over 450,000 students entering some form of engineering or technology program. However, since that time, the nation has experienced a 25% drop in students majoring in a field related to engineering. As part of this downward trend, student diversity also continues to suffer. Of the four million students graduating from high school each year, only two percent will earn an engineering degree, and only one percent of these graduates will be female. In addition, less than 15% of all high school students graduate without taking sufficiently rigorous math and science courses that will allow them to be successful in an engineering program[3]. Because of this current trend in education as well as the reduction in the number of students choosing engineering as a career, the federal government has placed a major emphasis on STEM (Science, Technology, Engineering, and Mathematics) outreach to K-12 students in the hope that the country can continue to produce a ready supply of engineers and technologist for the future. Money has been provided by many federal agencies to fund research and develop STEM fields in public education but has provided little comparative success for the amount of money expended. Between 1994 and 2004, the National Institute of Health invested 998 million dollars in STEM research and outreach. Likewise, the National Science Foundation spent a total of 997 million dollars, NASA 231 million dollars, the Department of Education 221 million dollars, and the Environmental Protection Agency 121 million dollars on STEM-based research[4].

Preparing students for fields related to engineering and technology is nothing new, just as the fact that more students have been needed in these fields at various points in our history. One can trace the roots of pre-engineering education to the Dutch in the 1650's. In the US, private career schools became commonplace in the 1820's, but the Vocational Act of 1917 was the first support the federal government gave to training individuals for fields related to engineering education at the secondary level. Due to the industrial revolution, the first half of the 19th century was formative years for career and technical education. Although many opportunities for career education in engineering and related fields were in the private sector, over time, public universities began to offer degrees, and federal acts, like the Land Grant Acts, Defense Acts, and others, formalized engineering and technical education into the system that exist today[5]. At Ohio State University, for example, Calvin Woodward and Professor Robinson in engineering established a manual training program as part of an existing engineering program *(Personal Communications with Karen Zuga, September 2, 2005).* Other programs followed at land-grant universities across the United States. These programs later became know as Industrial Arts Education and, currently, Technology Education. Individuals in Technology Education provided some of the first leaders who voiced the current rationale for pre-engineering education. A document, "Curriculum to Reflect Technology," written in 1947 by William Warner, an early leader in technology education, called for engineering education and training in the local public high schools. In the 1960's, two technology education leaders, Olson and DeVore, developed two curriculum projects, "IACP" and "Jackson Mills," which led to the current curriculum focus in technology education. These curricula provided more than just skill-based training, they also developed students' critical thinking, problem-solving abilities, and design abilities. Donald Maley's "Maryland Plan," developed in the 1970-80's, used an experimentation emphasis. This lead to a national focus on design in the 1990's and made technology education one of the main catalysts for pre-engineering education[6]. This also can also easily be recognized in the "State Career Clusters" curriculum project of 2001. Thus project established needed standardization for curriculum related to science, technology, engineering, and mathematics (STEM) by the US Department of Education[7]. The development of the new "Standards for Technological Literacy" in 2000, produced by the International Technology Education Association (ITEA), not only highlights areas of study for technology, but emphasizes engineering design, problem-solving, and the understanding of technological systems[8].

Engineering graphics and its role in engineering education is nothing new[9]. Various research studies have been conducted on students' interested in an engineering or technology career and the need for visual skills[10]. The profession of engineering graphics has researched areas in visualization, gender, and spatial abilities for the past 20 years and has found that students see the need for visual skills as they are related to engineering and technology career paths. Most pre-engineering based projects for secondary schools have some form of design or graphics as part of its program content to provide a hands-on approach that produces a better understanding of engineering and technology concepts. For example, in 1993 the National Center for Research in Vocational Education developed the Pre-Engineering Academy, a program designed to help states entice students into careers in engineering and technology. This academy approach had five areas of concentration, which included graphics. Within its graphics area, students took classes in engineering graphics and descriptive geometry as well as incorporated design elements into another concentration area, known as "strength of materials"[11].

Based on this background information, the authors of this paper have found that most pre-engineering approaches that include engineering graphics occur in one of the following ways. First, it is provided as a separate course in engineering that is taken at a high school or community college. These sometimes can be transferred to post-secondary institutions, through an articulation agreement, and engineering graphics courses are the most common courses involved in these types of agreements. Second, pre-engineering education is offered through academies. In this process, students are tracked into a series of classes that will help prepare them to pursue an engineering related degree upon graduation. Students can pick and chose from a variety of courses so they can custom tailor their course of study. Third, similar to the academy approach, is a set curriculum. In this process, students are placed into a curriculum where all courses are directly related to their field of study (i.e. pre-engineering), with little flexibility. Fourth, hybrid approaches that include summer camps for special interest groups who wish to study specific areas of engineering or after school programs that offer further study into engineering related areas[1].

II. CURRENT STATUS

"We should be concerned about the future because we will have to spend the rest of our lives there."(Charles Franklin Kettering, 1949)

Many projects have been funded at both the local and national level for engineering education. Though the investigative research conducted for this paper, the authors identified 53 pre-engineering based federal and state projects. Of these, 15 have engineering graphics and/or design as a role in the project. Based on this, the authors have provided a table showing only the current and recent past projects that include engineering graphics. See Table 1 for a listing of these projects.

Table 1 Pre-engineering related projects that include some form of engineering graphics and/or design

Project (both State & Federal)	**Description**	**Outreach**	**Graphics Type**
Technology and Science Connection	K-12 guide for incorporating engineering concepts into science and mathematics	Supplemental materials	Prototyping and design
Intro. To Mechanical Engineering	Partnership with k-12 teachers and engineering students	Service	Design and engineering graphics
The Science of Playgrounds	Hands-on experiments for k-12 linking science and engineering	Supplemental materials	Engineering Design
Design Technology and Engineering for America's Children	Introduces engineering design and problem-solving	Supplemental materials	Engineering Design
Bridge Engineering; Univ. of Missouri-Rolla	Allows elementary children to design and build bridges	Supplemental materials & Service	Engineering Design
Enrichment Program; SE Michigan Alliance for Reinvestment in Tech. Ed.	Eighth grade enrichment program for technical areas.	Service	CAD/CAM
Engineering Outreach Teams	Travel to a variety of k-12 programs promoting engineering education	Service	Design
Simultaneous Engineering Experienced by High School Students	Concurrent engineering as related to engineering design	Service	Engineering Design

Technology and Science Connection	Engineering design competition for k-12	Service	Engineering Design
Boosting Engineering, Science, and Technology	Engineering design competition for grades 7-12; new product inventing	Service	Engineering Graphics & Design
Summer Academy for Middle School Teachers; SE MI Alliance for Reinvestment in Tech. Ed.	For teachers and counselors to be introduced to technology and engineering-based subjects	Service	CAD/CAM
Infinity Project	Created a complete high-tech engineering curriculum for high schools	Curriculum Development	Engineering Graphics & Design
Project Lead the Way	High school pre-engineering curriculum	Curriculum Development	Engineering Graphics
Choctawhatchee Pre-Engineering Course	Course for high schools in Florida	Course Development	Engineering Design
Cal Poly Pomona's Workshop for Minority Engineering Program (MEP)	Outreach to bring minorities into engineering college programs. Learning CAD was used to reduce fear of technology	Service	CAD
IDEAs Increasing Diversity in Engineering Academics	Outreach to low income and first generation college students	Service	CAD
Pre-Engineering Academy (NCRVE)	High school curriculum based on the academy approach	Curriculum Development	Engineering Graphics & Descriptive Geometry

Citations 2, 12, 13, 14, 15, 16, 17

From the table above, one can see some common themes. The most obvious is the k-12 teacher involvement and the development of hands-on activities. Other themes include role model development, supplemental materials, problem solving and inquiry learning goals, and a focus on young students. Common methodologies used in projects were the development of both web resources and supplemental materials for teachers and students. Also, the sponsoring of engineering design contests and outreaches from college campus were methods used to engage students. One area, not commonly found as either a methodology or theme for projects, was professional development for teachers and college instructors. Although some projects mentioned in-service, none were found to offer any professional development for k-12 outreach related to engineering and technical graphics education[15].

III. ROLE OF ENGINEERING GRAPHICS IN TECHNOLOGICAL LITERACY AND PRE-ENGINEERING EDUCATION

Engineering graphics has been a part of pre-engineering education since its early beginnings, as it continues to be today. States and federal agencies as well as federal projects still see the role that engineering graphics can play in providing real-world examples and hands-on instruction that students need for professions in engineering. All current statewide curricula that exist in technology and technical education for grades 8-12 uses engineering and technical graphics as a catalyst for integrating engineering education into public school curriculum. For example, Virginia has a large number of courses in technology education that relate to our field, but two courses standout. “Introduction to Engineering” (8490) and “Advanced Engineering” (8491) are courses that both teach and use engineering graphics as part of the competencies that are to be mastered. Virginia also recently started a project, called “Children’s Engineering Convention,” to bring engineering activities into elementary programs, again with a strong emphasis in design and graphics[18]. North Carolina has engineering graphics throughout its technology education program, but one curriculum in particular, “Scientific and Technical Visualization I & II,” attracts students wishing to someday major in engineering or science. These courses develop good visualization skills and students’ abilities to communicate to a wide variety of audiences[19]. North Carolina is not the only state linking engineering to science through graphics and visualization as a pre-engineering curriculum. In New Jersey, a statewide project, PrE-IOP or ‘Pre-Engineering Instructional and Outreach Program,’ is using integrated science with engineering concepts (i.e. graphics and visualization) to attract historically underrepresented populations into engineering fields[20]. New Jersey is also currently revising their state’s curriculum for both elementary and secondary education to better reflect engineering education practices. Since the 1980’s, the New York Department of Education has offered a course, “Principles of Engineering,” that focuses on engineering graphics and design and plans to develop more courses like it in the future. Massachusetts has just developed and begun the implementation of new science and technology/engineering standards in their schools. Colorado and Colorado State University just completely changed their technology education degree to engineering education, again, with a focus on communications and engineering graphics. Australia has gotten into pre-engineering through technology education as well. As of 2006, a new technology course, titled “Engineering,” will be offered to students wishing to pursue a degree in this field. John Williams, from Edith Cowan University, indicated that the course is very much an engineering design-based course. *(Note: most of the information found in this paragraph came from the Council of Technology Teacher Education Listserv from September 2-18, 2005)*

As Table 1 indicates, Engineering graphics and design are part of many national projects. Some of the larger projects that are influencing national trends include engineering graphics as their major thrust for integration into the public school systems. One in particular, Project Lead the Way (PLTW), includes engineering and design throughout its courses. PLTW has to date developed a four-year scope and sequence of courses that students can take in high school that will lead them towards a career in engineering. The sequence of courses includes college preparatory mathematics and science courses as well as technology education. Also included in the course offerings are courses related to graphics. Currently, students in a PLTW program take "Introduction to Engineering Design" and "Engineering Design and Development," both which focus on problem solving through 3D modeling and concurrent engineering practices[21]. Yet another new project, currently being developed through the International Technology Education Association (ITEA) and the Center to Advance the Teaching of Technology & Science (CATTS), is "Engineering By Design." This program will bring about standards-based curriculum for technology education that will include engineering concepts. In this project, national curricula will be developed and distributed to CATTS consortium states that include two new classes, "Introduction to Engineering" and "Engineering Design." Both are communications-based and focus on the engineering design process. *(Presentation from Barry Burke at the STEC, October 2005).*

IV. DISCUSSION AND CONCLUSIONS

Many attempts have been made through the years to integrate and create successful pre-engineering programs both locally and nationally. If history has taught us anything, it is that change is constant and educators must embrace new initiatives as we move towards a better future for the students we teach. The authors of this paper have attempted to enlighten professionals in engineering graphics education on the role we have in pre-engineering education, both past and present. It can easily be seen that our field of expertise is a major focus for this new curriculum approach in the public high schools, and it importance continues to grow. So, if others see it as a fundamental area for pre-engineering education, what is it that we need to consider for the future of our discipline? We make the following suggestions.

First, the authors would like to see increased outreach to k-12 school programs, but with a concentration on visual literacy and understanding. If we are to truly give all students a good education in the United States, whether or not a student is an engineering future major are not, they should be technologically and visually literate. The visual and technical communications that we teach is imperative for most jobs and will be even more so in the future. Outreach to help students learn how to communicate to a wide variety of audiences will be the key in securing our role for future endeavors and growth as a discipline. Second, as post-secondary instructors and professors, we need to commit some of our service time to working with state leaders in departments of education and public instruction. This will ensure that when curricula are developed, they are up-to-date, accurate, and adhere to their intended purpose. A large number of professionals in education tell the authors that it must be great to be in a field that is growing. However, as a field like engineering graphics grows, it can become difficult to make sure quality is being maintained, and our discipline is no exception; therefore, we need to work with state officials and help in the development of course materials, curricula, and in-service education to ensure appropriate standards are implemented and that correct information is conveyed. Third, we need to work with mathematics, science, and technology education teacher associations to provide our expertise, but, above all, to show our support for their new programs. Whether you like it or not, pre-engineering education is here and most likely will stay for some time; therefore, we as a discipline need to get involved in both student and teacher organizations and help direct the future for our discipline. So often we hear engineering and technical graphics associated with career and technical education, but as a discipline we can easily integrate across most, if not all, disciplines and need to work with professional teacher educators in this integration process. Disciplines in mathematics, science, and technology need our know-how to develop successful curricula for areas in pre-engineering education and to help demonstrate the need for visual literacy among all students; we just have to make the effort. This can be accomplished many different ways, but one way in particular, which the authors of this paper found to be missing, is a concentration on professional development. Many local, regional, and national pre-engineering projects exist, and most focus on material development rather than on an extensive professional development plan. Therefore, we would like to suggested that as professionals in our field we work with local and state school systems as well as write grant proposals that will lead to a more developed and refined professional development plan for our area, one that teachers, counselors, and teacher educators would see the benefits of and participate in. A way to start this process nationally could be that the Engineering Design Graphics Division (EDGD) host a national conference for pre-engineering curriculum leaders throughout the country to determine exactly their needs and how we can assist them. This national conference could be in conjunction with the newly formed K-12 Outreach Division of the ASEE and become an annual event.

As a final thought, if pre-engineering curricula is going use our discipline as one of the main stays in secondary education, the EDGD division should develop a session at its annual mid-year meeting that specifically addresses k-12 outreach issues. This session could be for research in the growing field of pre-engineering education as it relates to our discipline or just graphics education in general. Either way, our field of study is as popular as ever in the public schools, as it is in higher education, but no formal mechanism is in place to provide communication between the two groups. If we are to truly grow in both secondary and post-secondary education, we need to have something that will articulate information and understanding between all instructional levels that are a part of our field, whether it is a middle school drafting teacher, or a college professor in our field, we are all dedicated to helping students.

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