2006-399: K-12 OUTREACH FOR ENGINEERING AND TECHNICAL GRAPHICS: WHAT IS OUR ROLE?

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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 the 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 so new to states curricula. Considering this new era of pre-engineering education and student's needing to receive a foundation in areas related to engineering before they come to college, professionals in our field need to 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 the expected outcomes? Also, is there research that supports our task as engineering graphics educators to become involved in this new curricula initiative in secondary education and how will this national effort effect the students we will have in our classes once they chose to attend college. Although many of these questions can only be answered in theoretical terms, a foundation of history and what professionals in our field and others are doing may help the engineering graphics community decide the position we should engage in pre-engineering education.

This paper is designed to give the reader insight as to what is happening in this new pre-engineering initiative from both secondary and post-secondary views. Information about the types and kinds of initiatives currently underway at the national level will be presented as well as what people in the engineering graphics community is doing in meet this pre-engineering curricula need. Conclusions will include a theoretical framework as to what professionals in our field can do to aid in the promotion of engineering design graphics into 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 developing the US economy. Many companies consider engineering the "driving-force" behind their success and growth that will help each remain competitive in the global market place in the coming years. Considering this, many professionals in the fields of education and engineering feel that it is imperative that everyone in our society have technological competence and the ability to create, use, manage, and assess technology, including young students in our k-12 schools. Statements like the ones mentioned above are being made throughout the country by business and education leaders, and at the same time, elementary and secondary students interest in technology and engineering disciplines continue to fade each year. 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 towards fulfilling these needs and deficiencies, but more is needed from a variety of disciplines from both public and private agencies[1].

Engineers and technologists are important and vita to the profitability of the US economy. The U.S. Department of Labor statistics reveal that 20% more engineers are needed over the next decade[2] and that Engineering education had its "peak" of student majors in the early 1980's with over 450,000 students entering into some form of engineering or technology program. But since that time, the nation has experienced a 25% drop in students majoring in a field related to engineering. Included in this downward trend, diversity continues to be a struggle as well. As of to date, consider the statistic that of the four million students graduating from high school each year, only two percent will earn an engineering degree, and only one percent of all high school graduates that are female will obtain a similar degree. Less than 15% of all high school graduates have had sufficient rigorous math and science courses that will allow them to be successful in an engineering program[3]. Because of this current trend in education and students not choosing engineering as a career, the federal government has placed a major emphasis in STEM (Science, Technology, Engineering, and Mathematics) outreach to K-12 students so that the country can continue to have a ready supply of engineers and technologist for the future. Research money has been given out by many federal agencies to research and develop STEM fields, but with little success for the amount of money invested to research and improve upon STEM education in our public schools. As of 2004, and relative to the last 10 years, the National Institute of Health as invested 998 million dollars in STEM research and outreach. The National Science Foundation is no exception with a total of 997 million dollars, and NASA with 231 million dollars of STEM research, as well as the Department of Education at 221 million and the Environmental Protection Agency at 121 million dollars in STEM-based research dollars[4].

Preparing students for fields related to engineering and technology is nothing new, just as well as the fact that more students are needed in these areas at different points in our history. One can trace the roots of pre-engineering education to the Dutch back in the 1650's. In the US, private career schools came commonplace in the 1820's and in 1917, the Vocational Act was the first time the federal government became involved in supporting training in fields related to engineering education at the secondary level. During the first half of the 19th century, we established the formative years for career and technical education thanks to the industrial revolution. Although many opportunities for career education in engineering and related fields were in the private sector, over time, the public universities began to offer degrees and federal Acts like the Land Grant Acts, Defense Acts, and others formalized engineering and technical education as we see it today[5]. At Ohio State University for example, Calvin Woodward and Professor Robinson in engineering established a manual training program as a 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 came know as industrial arts education and currently, technology education. Considering this, technology education had some of the first leaders in what has led to the current rationale for pre-engineering education. In a document titled "Curriculum to Reflect Technology written in 1947 by William Warren, one of the first leaders in technology education, called for engineering education and training in the local public high schools. Later, two technology education leaders by the names of Olson and DeVore in the 1960's developed curriculum projects titled "IACP" and "Jackson Mills" that led to the new curriculum in technology education that provides more than just skill-based training, but curricula that develops students literacy in critical thinking, problem-solving and design. Donald Maley and the research and experimentation emphasis in his "Maryland Plan" in the 1970-80's and the national focus on design in the 1990's has made technology education one of the main catalysts for pre-engineering education[6]. This can also easily be recognized in the "State Career Clusters" curriculum project in 2001 that established needed standardization for curriculum related to science, technology, engineering, and mathematics (STEM) from the US Department of Education[7]. Also, by the development of the new Standards for Technological Literacy in 2000 produced by the International Technology Education Association (ITEA) that not only highlight areas of study for technology, but has direct emphasis on engineering design, problem-solving, and the understanding of technological systems[8].

Engineering graphics and its role in engineering education is nothing new to engineering education[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 do see the need for visual skills as they are related to engineering and technology career paths. Most projects that are pre-engineering based for secondary school do have some form of design or graphics within its program's content to aid in bringing about the hands-on approach that allows for better understanding of engineering and technology concepts. For example, the National Center for Research in Vocational Education in 1993 developed the Pre-Engineering Academy for states to use that will lead students towards careers in engineering and technology. This academy approach had five areas of concentration, one being graphics. Within the graphics area of study, students took classes in engineering graphics and descriptive geometry, as well as incorporated design elements into another concentration area called strength of material[11].

Considering the above information, the authors of this paper have found that most pre-engineering approaches that include engineering graphics come in one of the following ways. First, as a separate course in engineering and sometimes can be articulated to post-secondary institutions through some type of articulation agreement. The authors have also found that engineering graphics courses are the most common for these types of agreements. Another approach to offering pre-engineering is through the academy approach. 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 course offerings as they custom tailor their curriculum. A third approach that is similar to the academy approach is to use a set curriculum. This process is where students are placed into a curriculum and all courses are directly related to their field of study (i.e. pre-engineering), with little flexibility. Hybrids of these approaches include summer camps for special interest groups or to study a specialized area of engineering, or after school programs that brings 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 playing a role within the project. Considering this, the authors of this paper decided to include only those current and recent past projects that include engineering graphics in their program or project. 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	Travel to a variety of k-12 programs	Service	Design

Outreach Teams	promoting engineering education		
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 listed above, one can see some common themes throughout each project. The most obvious theme is the k-12 teacher involvement and the need for developing hands-on activities. Other themes include role model development, supplemental materials, problem solving and inquiry learning goals and the focus on young students.

Common methodologies used in projects were the development of both web resources and supplemental materials for teachers and students. Also, sponsoring 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 where 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 and continues even today. States and federal agencies and project 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 do use engineering and technical graphics as a catalyst for integrating engineering education into public school curriculum. For example, Virginia has many courses in technology education that relate to our field, but two courses standout from the others. These courses titled "Introduction to Engineering" (8490) and Advanced Engineering" (8491) both teach and use engineering graphics in the list of competencies that are to be mastered. Virginia has just started a project called "Children's Engineering Convention" to bring engineering activities to 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 titled "Scientific and Technical Visualization I & II" attracts students wishing to someday major in engineering or science by learning to create good visualizations and can communicate to a wide variety of audiences[19]. But, 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 titled PrE-IOP, or Pre-Engineering Instructional and Outreach Program is using integrated science with engineering concepts (i.e. graphics and visualization) to get historically underrepresented populations into engineering fields[20]. New Jersey is also currently revising the state's curriculum for both elementary and secondary education that will better reflect engineering education practices. The New York Department of Education has had a course titled "Principles of Engineering" since the 1980's that has a focus on engineering graphics and design and will be developing more courses like it in the future. Massachusetts has just developed and started to implement the new science and technology/engineering standards in their schools. Colorado and Colorado State University has 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 curriculum 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 and 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)*

Engineering graphics and design are in many national projects as seen in Table1 of this paper. Some of these larger projects making and setting national trends do include engineering graphics as their major thrust to be integrated into the public school systems. One in particular, Project Lead the Way (PLTW), does include engineering and design throughout its courses that are offered. PLTW has developed to date 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 does include college preparatory mathematics and science courses, as we as technology education. Also included in the course offerings are courses related to graphics. Currently, students in a PLTW program will take "Introduction to Engineering Design" and "Engineering Design and Development"; both these courses focus in on problem solving through the learning of 3D modeling and concurrent engineering practices[21]. Yet another new project that is currently being developed through the International Technology Education Association (ITEA) and the Center to Advance the Teaching of Technology & Science (CATTS) is titled "Engineering ByDesign". This new 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 titled "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. EDGD Division Outreach to K-12 Education

To determine if any of the members of the EDGD Division of ASEE were involved in K-12 outreach and their members' feelings on the subject, a survey was sent out by email to the individuals who participate in the EDGD listserve as well as distributed at the 2005 Midyear Meeting of the division. The ten individuals who responded to this survey were primarily those already involved in out reach activities, so the information discussed below is a reflection of individuals who largely are interested in this subject.

The survey asked if the division should be involved in outreach to K-12. All but one respondent strongly felt that it should be part of the division's mission. Reasons given for involvement with K-12 students related to the need to introduce them to fields in Engineering, increase their visualization skills, improve their visual problem solving skills, and improve their technological literacy.

The survey also asked individuals if they were or had been involved in K-12 outreach activities. Six of the respondents indicated that they had been involved in these types of activities. The majority of these activities were summer camps and activities designed to familiarize students with the fields of engineering. Three respondents were involved in Project Lead the Way (PLTW), and one worked with 7th and 8th grade girls to increase their math skills.

When asked what Engineering Design Professionals bring to K-12 programs, a variety of answers were given. These included an understanding of career opportunities in engineering, a development of visualization and problem solving skills, an understanding of the graphical language and the design process, and opportunities to be involved in real-world experiences. In terms of technical expertise included providing expertise in computer-aided drawing and modeling concepts, and opportunities to be involved in hands-on activities.

The respondents gave a variety of answers to the question related to ideas and strategies that could be used by engineering graphics to become involved in outreach. These included some of the most diverse answers given on the survey; however, the dominating responses related providing K-12 teacher training and summer camps or weekend workshops to introduce middle school and high school students to engineering graphics and engineering practices in general as well as student competitions. Other suggestions included involvement in curriculum advisement, development of a marketing strategy to encourage parents to support the inclusion of graphics in state curricula plans, development of mentoring or cooperative projects with interested companies, endorsement of PLTW programs, demonstration of the relationship of graphics to engineering, and development of a relationship technology education associations to create a link between engineering graphics and public school teachers who are members of these organizations. There was a further suggestion that we should develop standardized graphics tests, levels and certification for K-12 teachers.

Additional comments by three respondents demonstrated the interest of these individuals in involvement with K-12 students and the importance they assign this area. Two stated that this is a significant area that the Engineering Design Graphics Division as well as other professionals in our field should be involved in, and we were not doing enough; however, another worried that if a tenure-track instructor is in a program or department that does not include this type of research and service as part of their agenda, it would be difficult for them to make much of an impact.

V. 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 will always be present and that we as educators must embrace new initiatives as we grow towards a greater and better future for the students we teach. The authors of this paper made the attempt to enlighten professionals in engineering graphics education as to 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 continues to grow. So, what is it that we need to consider for the future of our discipline if others see it as a fundamental area for pre-engineering education? We make the following suggestions.

First, the authors would like to see more 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, all should be technological literate and with that, visual literate as well. The visual and technical communications that we teach is imperative for most jobs at the present, and even more so for the future. Outreach to get students knowing how to communicate to a wide variety of audiences will be key to securing our role for future endeavors and growth as a discipline. Second, we as post-secondary instructors and professors need to commit some of our service time to working with state leaders in departments of education and public instruction so that when curricula is developed, it is up-to-date, accurate, and does its intended purpose. A lot of professionals in education tell the authors that it must be great to be in a field that is As a field like engineering graphics grows, it can become difficult to set controls that make sure quality is being maintained, 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 make sure standards are kept and that correct information is being conveyed. Third, we need to work with mathematics, science and technology education teacher associations as to provide our expertise and see that quality is being maintained, but above all, to show our support for these new programs. Whether you like it or not, pre-engineering education is here and most likely will stay around for some time, therefore, we as a discipline need to get involved in both student and teachers organizations and help direct the future for our discipline. So often we hear engineering and technical graphics associated with career and technical education, but we as a discipline that can easily integrate across most if not all disciplines need to work with professional teacher educators in this integration movement. Disciplines in mathematics, science and technology need our know-how in order to develop success curricula for areas in pre-engineering education and to help initiative 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 that 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 materials develop, few develop extensive professional development plans. Therefore, it is suggested that we as professionals in our field work with local and state school systems, as well as develop proposals for grants that will lead to a more developed and refined professional development plan for our area that teachers, counselors, and teacher educators would see the benefits and participate. One-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 and see exactly what needs they have that we can be of assistance with. This national conference could be in conjunction with the newly formed K-12 Outreach Division of the ASEE and could lead to an annual event. A final thought would be that if pre-engineering curricula is going use our discipline as one of the main stays in secondary education, that the EDGD division develop a theme session at it's annual mid-year conference that particularly addresses k-12 outreach issues. This session could be for research in the growing field of pre-engineering education as it relates to our field, 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 for communications 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 that are a part of our field, whether it's a middle school drafting teacher, or a college professor in our field, we are all dedicated to helping our students.

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