Engineering Technology Programs Outreach to K-12

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Abstract

The Engineering Technology (ET) degree emphasizes hands-on application and implementation. Graduates holding this degree play a valuable role in economically growing the US and keeping it internationally competitive. However, "engineering and engineering technology, are widely misunderstood… the public sector (employers, students, high-school counselors, politicians and the general public) needs to be educated as to the particular value of each," according to Engineering.com [1]. The National Academy of Engineering states, "Unlike the much better-known field of engineering, engineering technology is unfamiliar to most Americans and goes unmentioned in most policy discussions about the US technical workforce. This is even though workers in this field play an important role in supporting the nation's infrastructure and capacity for innovation" [2].

In the above context, outreach by ET programs to K-12 constituents including students, teachers, and even parents is extremely important. The outreach activity can take many forms. It may be as simple as a visit to classroom either by ET faculty or students to a K-12 classroom for a show and tell. Inviting high school and middle school students and teachers to engineering open houses and campus visits can be another effective method. In addition to these traditional methods, new and innovative methods of outreach can use social media tools to reach out to students and parents. Another method for increasing awareness about ET programs is via career day events. This paper discusses various methods for outreach including some case studies of tried and tested methods.

1. Introduction

The rapid evolution of technology in the 21st century is changing the needs for the workforce in general and more specifically in STEM fields. Professional societies, such as the American Society for Engineering Education and the NAE, call for new educational approaches that focus on the hands-on, interdisciplinary, and socially relevant aspects of STEM, specifically highlighting engineering as a discipline that can meet these goals [3]. Earlier implementation of STEM education often missed the engineering content. The S, T, E, and M are separate and not equal. The inequality really becomes clear, for example, when one considers the fact that science, technology, and mathematics have national standards, and since 2014, all three have national assessments.

To date, only Massachusetts mandates engineering in its preschool. Although it has been clear to many educators that students must be introduced to engineering at early ages, K-12 educators are not proficient in this field. Several universities have opted for outreach programs through various form, the common goal is to increase the students' awareness and interest in engineering [4].

Project-based learning has proven record as a teaching tool. Project-based learning is a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks [5]. The hands-on nature of engineering projects offers students an opportunity to promote critical thinking, teamwork, writing and leadership skills. That hands-on projects should be fun and linked to real world engineering problems. The Young Engineers of South Texas (YESTexas) a project where high school students were exposed to STEM concepts through hands-on engineering projects and technical activities attracted qualified students to the engineering disciplines. It was observed that projects that related to real-life situations with in-depth analysis were highly appreciated [6].

It is important that students obtain information about preparing for colleges during early in their academic life. Educationally and economically disadvantaged children face challenges in their home, community, and schools. This can limit their opportunity to engage in a curriculum that builds intellectual capacity. Researchers have identified the following key components of successful academic development programs [7]:

- High standards for program students and staff
- Personalized attention for students
- Adult role models
- Peer support
- K-12/program integration
- Strategically timed interventions
- Long-term investment in students
- School/society bridge for students
- Scholarship assistance
- Evaluation designs that contribute results to interventions

It is also found that parental education levels have a significant effect on the college aspirations of the children [8].

Today's technological society needs an educational system that prepares all students in STEM field. In order to improve STEM education, resources and outreach at middle and high school may be too late for some students. K-4 teachers are expert on how their students learn but lack technical knowledge. Engineers, on the other hand, are technical experts but lack the understanding how students learn. Engineers and teachers should collaborate to provide a realistic picture of what engineers do to K-4 students [9].

Arizona Science Lab (ASL) started project-based STEM workshops for grades 4-9, which consisted of 1. demonstration of the underlying physical laws and engineering principles through rich student/teacher interactions; 2. design, build; and 3. wrap-up phase. Carrying out simple engineering projects allows children to understand problem-solving steps undertaken in real-world engineering solutions. Through these real-world engineering projects, students come to know about global and local impacts of engineering. Showing students that these engineering solutions are self-achievable increases the students' understanding of engineering [10].

The author, in his NSF-funded project titled "Marine Tech," has demonstrated that PBL and engineering competitions can increase students' awareness, comprehension, and understanding of STEM careers and educational pathways leading to these careers [11,12,13].

2. Types of Outreach Activities

A. Open Houses

Open houses help to promote awareness of university degrees within high schools. Members of the university visit the campus and explain to high students and teachers the degree programs offered, convey the idea of university life, and show them all the university facilities such as laboratories, the data room, and computer center. Members of the university are encouraged to take part in other events offering the opportunity to publicize the institution, such as cultural days and conferences. Meetings between university and high school students are arranged so the former share their knowledge, university experiences, and future employment prospects [14]. The faculty and staff of the Batten College of Engineering and Technology warmly welcome teachers, counselors, prospective students and parents to learn more about Old Dominion's engineering and technology programs and facilities through our Engineering Open House Expo. This event is intended to introduce secondary school students to the field of engineering. Engineering lab tours provide the opportunity for attendees to witness demonstrations of the exciting ongoing research at the college. Representatives from professional and student engineering clubs and societies are present.

B. Presentations to K-12 Students

Classroom presentations by engineering faculty and students offer opportunities for collaboration between universities and school systems. These presentations can be done either by engineering students or faculty. Several schools organize STEM days, during which they invite faculty from local universities to participate and present. These visits may often lead to funded collaborative research projects, further increasing the bond between four-year institutions and K-12.

C. K-12 Partnerships in Research Projects

The Marine Tech Project, funded by the National Science Foundation, and the Shipbuilding and Repair Career Day Events (SBRCD) project, funded by the National Shipbuilding Research Program, are two examples of K-12 partnerships via funded research projects. These projects attempt to engage students in STEM tracks and increase their awareness about shipbuilding and repair careers by developing project-based learning kits and associated instructional modules. Four marine kits and four instructional modules were developed under these two grants to encourage creative thinking and keep students engaged in shipbuilding and repair processes. The teacher-training component of these projects has provided training in using and implementing these modules.

Old Dominion University, Norfolk State University and University of Louisiana, in collaboration with marine industry and local school systems, partnered to improve STEM preparation using innovative experiences for students and teachers in nation's major shipbuilding and repair areas. The Marine Tech project served 60 students in grades eight through twelve, over a period of three years, by providing 144 hours of instruction and hands-on learning experiences in the fields of marine engineering and physical sciences with a shipbuilding focus. The program included eight Saturdays during academic years, with an additional two-week academy during each summer. MarineTech's progressive curriculum covered foundational skills and knowledge of basic physical science, as it relates to shipbuilding, through the application of these principles in a culminating ship design competition. The curriculum was enriched with program activities such as field trips to shipbuilding and repair companies, marine science museums, and career day events.

Under the SBRCD project funded by the National Shipbuilding Research Program, four hands-on activities were developed for middle and high school students. The project team, consisting of university faculty, industry personnel, school and community college teachers, developed these four simulation-based hands-on learning kits called Marine Kits, MK-1-4, and five instructional modules, IM-1-5, to complement the hands-on activities. These activities and associated curriculum have been designed to provide an integrated STEM learning experience for middle and high school students.

The learning kits utilize the 5E learning model that has been used successfully for STEM instruction. Figure 1 shows 5E learning cycle used in the Marine Kit activity. Students were divided into four to five groups to conduct hands-on activities for each module. Figure 2 shows the hands-on activities performed by students during ship terminology and ship structures modules.

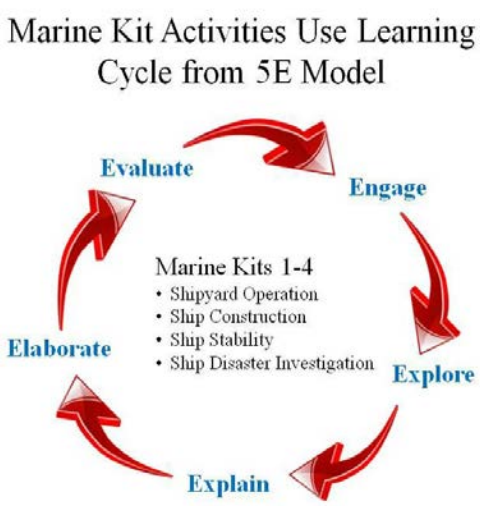

Figure 1. 5E learning cycle in Marine Kit activity

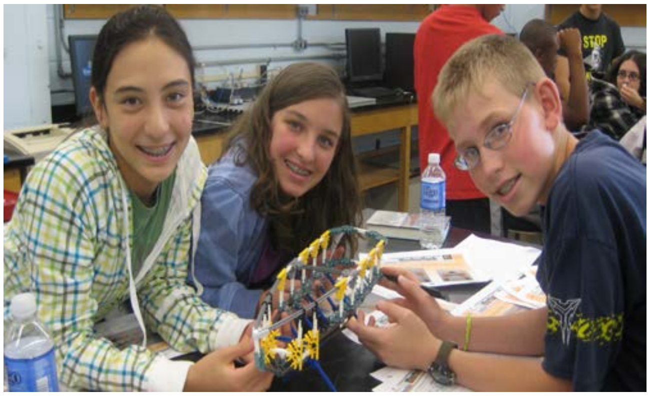

Figure 2. Hands-on activities on IM-1 and IM-2

Marine Tech was designed around a project-based learning framework. By understanding how student thinking may have changed as a result of this kind of instruction, we can begin to understand how students understand the relevance of this work. This would support future curriculum designs and recommendations to the field about implementing similar work.

Note the highest gains were in how project work related to real-life problems, the importance of interdisciplinary learning, and the understanding of inquiry-based learning (asking questions vs. receiving instructions). The least gains showed in the significance of the main topic; something we might attribute to the fact that many of the marine engineering principals were ancillary to the science content covered by the grade-level standards, and that in many cases, MarineTech activities occurred outside of the formal classroom setting (in after-school clubs, etc.), thus heightening the "project activity hands-on" aspect and lessening the content focus.

During each year, teachers demonstrated interest in Marine Tech content topics as well as general instructional strategies aligned with project-based learning. The professional development strand consisted of formal 2-day meetings each summer and less formal but still valued participation in the Saturday student academies during the year.

D. Summer Camps

Strategies using summer camps to introduce potential students to STEM disciplines are one example of how universities can increase enrollment in these fields. Summer camps focusing on various engineering fields have been conducted to deliver engineering design lessons, from different branches of engineering, by numerous educators. Some of these camps offer their programs mainly to urban area students [9], [15], while some require camp fees [15], [16], which can be an impediment for students who are financially disadvantaged. The camp experience clearly demonstrated that the hands-on nature of the engineering projects offered the participants an opportunity to promote critical thinking, teamwork, writing, and leadership skills. Projects that were related to real-life situations with in-depth analysis and clear identifiable end results or products were highly appreciated.

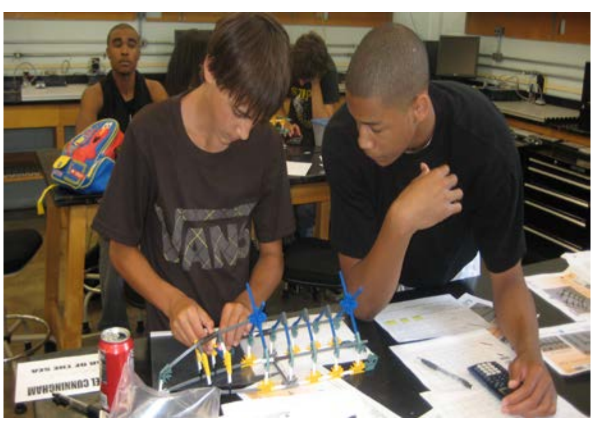

Figure 3. Marine Kit 1 and 2 activity

Figure 4. Industry booths at the Shipbuilding & Repair Career Day event

Figure 3 shows students performing hands-on activities with Marine Kits 1 and 2 during the summer workshop organized by the Marine Tech project. Figure 4 shows students participating in the Career Day event. Comments at the end of the workshop reveal that students enjoy learning about ships, ship construction, ship design and operations.

E. Career Day Events

SBRCD offered a one-stop shop for middle and high school students looking for career opportunities in the shipbuilding and repair industries. It included hands-on activities to provide realistic experiences about the work environment and processes that are used in the shipbuilding and repair industry. SBRCD brought together all the players in the industry to provide a comprehensive career resource event including shipyards, professional organizations, contractors, apprentice schools and trade groups. The event included programs for counselors and teachers to educate them about the needs of the shipbuilding and repair industry.

SBRCD would address the knowledge gap that exists among middle and high school students about careers in the shipbuilding and repair industry, as well as the need for a positive industry image among students and the general public. SBRCD brought together shipbuilding and repair companies to provide a daylong educational environment for students to learn about various career options in shipbuilding and repair.

Middle and high schools within a 100-mile radius of the three major ship construction and repair regions (Hampton Roads, Biloxi, and Seattle) will be invited to participate in these career day events. A dedicated website will provide information to participants. The learning labs and hands on booths will not only include trade business activities but also simulation activities related to business processes. Shipbuilding companies, contractors and professional societies will be invited to have booths to provide career information.

The SBRCD project included seven main components:

- Workshops for teachers and counselors in shipbuilding and repair operations
- Learning labs or hands-on booths for welding, mechanical, electrical and other trades
- Heavy equipment displays and operation during industry tour
- Industry booths including associations and private companies displaying industry corporate information
- Design and development of simulation kits for middle and high school students
- Training of counselors and teachers in the use of these simulation kits
- A virtual career resource center.

F. Professional Development of K-12 Teachers

Professional development of teachers is a key component of a successful outreach program. The needs reported most frequently by school division leaders include a) concentrated assistance in math and science instruction; b) better math and science preparation for teachers; c) professional development to encourage secondary teachers to have high expectations for all students and to use a wide repertory of instructional strategies to meet student needs; d) professional development that is closely linked with curriculum; e) professional development on research-based practices and better ways to manage use of curricular materials; and f) anytime, anywhere support for teachers.

Professional development for teachers can be done either through a funded project by a state agency or a federal government agency. For example, most states offer funding for teacher professional development via No-Child-Left-Behind and Math-Science Coalition Partnership programs. The projects discussed in this paper were funded by the National Science Foundation, Virginia Department of Education and the National Shipbuilding Research Program.

Twenty middle school and high school teachers participated in the Marine Tech workshop for teachers conducted at three locations of the project. Teachers, working in groups, built a container ship out of a cardstock paper and estimated its weight while working on a shipyard operations kit. With a focus on designed world, Marine Tech teachers enhanced their technological and pedagogical knowledge in integrating STEM concepts in instruction. In small groups, the teachers collaborated to create a collaborative project that can be implemented during the school year.

Figure 5. Teachers workshop

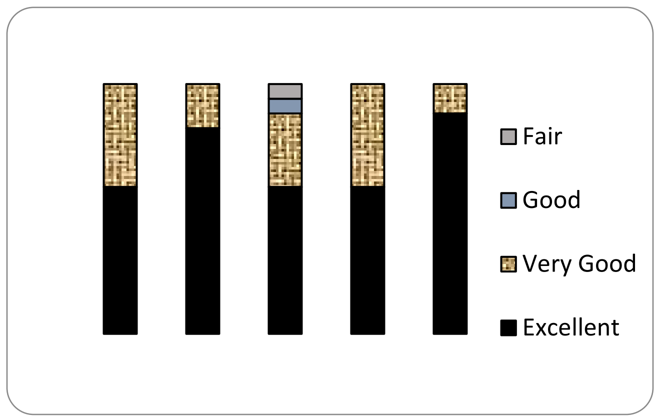

Figure 6. Plot of teachers' responses

Figure 5 shows teachers participating summer workshop, and Figure 6 shows the results from the evaluation of teacher workshop conducted during summer 2009. The chart shows that majority of teachers believed that the workshop using marine kits was extremely beneficial to them and that they enjoyed the hands-on activities.

Many colleges focus on improving engineering skills of K-12 teachers. Teachers who are trained in basic engineering principles and methods of teachers are comfortable sharing this knowledge with their students. This helps teachers to show connection between math, science, and engineering and the real world [17].

Providing teachers with enough training to instill the technical skills and confidence they require is the key to success. Role-playing is one of the unique forms that teachers can employ to present engineering material. It can help to engage and motivate students with new topics of instruction and can provide redundancy and reinforcement in completed topics [18].

Though workshop instruction, demonstrations, and hands-on activities are important, the networking and sharing among engineering faculty and K-12 educators is important as well. This networking can help K-12 educators stay connected to the advances in engineering and technology and provide resources for developing course curriculum [19].

G. Outreach Programs Focused for Girls

During last ten years, several projects have attempted to attract more women and minority into engineering careers. A survey of students in grades 9-12 indicated that only 2-3% of women in high school express an intention to study engineering; conversely, 16% of high school men declared that they plan to pursue an engineering degree [20]. Batten College of Engineering (BCET) and the Girl Scouts of Colonial Coast collaborated in 2017 on a project [21] funded by Office of Naval Research to attract more girls to engineering careers. It was observed that there are numerous factors that have been linked to the low numbers of women in engineering as well as the low number of girls interested in pursuing technical careers, notably the "perceived chilly climate" and lack of female mentors and role models [22].

3. Conclusions

There is considerable lack of awareness among the general public about engineering technology programs and these programs are often confused with engineering programs. In the above context, outreach activities are very important in informing the public. Theses outreach activities can take many forms, from open houses to collaborative research projects to summer camps and career day events. One example of the research project and career day event is the Marine Tech project, which has successfully developed and integrated project-based learning activities within the middle and high school curriculum. The Marine Kit activities and the instructional modules developed under this project complement the standards of learning for middle and high schools. Student learning is enhanced by incorporating project-based learning activities where students work in groups to accomplish problem solving. Students' comments from course evaluations indicate that students find these learning experiences very enjoyable. Participating teachers believed that the activities were well designed and engage students in classroom. Such collaborative projects can go a long way in attracting students to engineering technology programs.

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