What Does It Take
To Make K-12 Engineering Education Sustainable?

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Introduction

In the past decade there has been significant increase in the commitment of engineering schools, departments, and individuals to support engineering learning in the K-12 environment. As in any good engineering project, there is more than one solution. Looking across the spectrum, a wide variety of types of these K-12 outreach programs exist, ranging from single day student based experiences to professional development and engineering internship opportunities for teachers, with a varied assortment of programs in between. Each type of program brings a level of success, through the inclusion of engineering as a commonly used word and the introduction of learning about engineering as a concept for all types of students. But what kind of programs need to be in place to create a sustainable inclusion of engineering in the K-12 curriculum? And, how do we measure that sustainability in an area that is still in its infancy?

Discussion

The most common type of K-12 outreach program in engineering is a direct experience for the students to participate in a project that involves some engineering, often along with science. These programs have a fair amount of variation within themselves, but a typical approach is for the students to attend from one to several days of a 'learning camp' environment that guides them through a focused type of activity. In the state of Massachusetts, some examples of this are the Science Saturdays held by the University of Massachusetts, Amherst, Camp REACH held by Worcester Polytechnic Institute, Design Camp held by the University of Massachusetts, Lowell, and LEGO Camp held at Tufts University. The students who participate in these events all rate them as fun, worthwhile, and indicate that the experience has made them either change there opinion about engineering and science, or that they would now consider pursuing a career in these areas. Both are highly worthy outcomes.

Professional development workshops for current teachers are another avenue for outreach. These workshops provide the teachers with knowledge in multiple components; engineering content, links between engineering – science – mathematics, and connections to relevant everyday things. These are done so that they are made grade level appropriate for the teacher. Workshops like these vary as much as the student experiences. Some, like the introductory NSF Pre-College Engineering for Teachers workshop and the Intel funded Engaging Engineering, are half day experiences offered to whet the teacher's appetite and provide a single type of engineering activity for them to utilize in their curriculum. Others are much more intensive, requiring the teachers to commit to a longer term workshop, from 4 – 10 days, that spends time providing in-depth content discussions, multiple types of activities, and development time for internalizing the material. Examples of these are the Massachusetts Department of Education funded Content Institutes which are done in conjunction between a school district and an institution of higher learning, and the ROBOLAB™ curriculum workshops held by Tufts University. Teachers who participate in these workshops agree that engineering as a subject is relevant and useful for their students to learn, and it makes strong connections to science learning in an everyday context.

K-12 engineering activities are another outreach piece often come about as a result of the student experiences and teacher professional development opportunities. These are typically developed to give structured ideas on how to do an engineering activity, and link it to real world experiences. In the student experiences, they guide the learning and activities done by the students. For the teachers, they provide insight and ideas that can be used within their classes.
Making these already developed and tested resources available for others to use is invaluable, as it would remove the activity development and testing time requirement for outreach providers and it also provides a resource for teachers looking for engineering ideas. Many individual programs have this resource for themselves. One national based resource currently exists at www.prek-12engineering.org[2], and another one, TeachEngineering[3], is being developed as part of the NSF National Science Digital Library (NSDL).

As mentioned previously, each type of these programs has its value in the K-12 engineering outreach arena. But are they just neat individual projects or are they making a contribution to sustainable inclusion of engineering in the K-12 curriculum? What is the definition of sustain? Sustain[1]: to keep in existence; keep up, maintain or prolong. Then, if it is our goal to create a sustained inclusion of engineering we need to look at what impact the types of programs have on the sustainability. To date, what little K-12 engineering research has been done has focused on student outcomes and teacher confidence with the material. Nothing has been done to investigate the duration of programs and the influential factors. Since there is no data to draw from for this discussion, let's look at a case study and its impact.

The School of Engineering at Tufts University has a fifteen year history of doing engineering outreach to the K-12 community. In the beginning, individual engineering faculty members wanted to share some of the neat, current research with which they were involved with middle school and high school students. They would each go to schools and run a 'gee whiz' type of science and engineering experiment for students. While the teachers and students loved the opportunity to have the faculty member there (a break from the normal class, and a cool new idea to watch) there was no real learning for the students or ownership by the teachers to continue the conversations around the topic.

As a next step, to try to get teachers involved with the teaching of engineering along with science, grants for two different types of teacher workshops were written and funded. One, from the Pew Charitable Trust, focused on providing professional development around developing engineering activities for familiar things to the students and teachers. Each of the three years focused on the separate concepts on how these items (toilet, bicycle, and toys) involve science and engineering. The second one, from NASA LTP, focused on using Lego robotics to include engineering with space science. The hoped for outcome did occur - when teachers returned to their classes they implemented at least one of the activities which they had experienced in the workshop. However most of them were hesitant to try any additional activities, feeling that they were not strong enough in the content area to be able to explain it to their students. In the next and all future rounds of professional development workshops, specific time is spent on providing a large amount of time on supporting content and development time for the teachers to plan specific areas in their curriculum that they will also include engineering activities. This has been a more effective model, with the teachers comfortable implementing the ideas they worked on during the workshop.

In order to help the teachers have additional activities, work was done with funding from the Noyce foundation, to develop, test and document engineering based activities that were grade appropriate and low cost. These activities were developed with teachers, engineering faculty, and engineering students participating in the process. The result of this the website www.prek-12engineering.org, a resource that can be used during workshops or by teachers in the classroom.

Concurrent with the activity development and continuing workshops, the Tufts engineering faculty also spent time working with K-12 students, testing and observing the interest, engagement and understanding that they had of the activities. Programs for the students ranged from week long Lego camp to a summer long program for middle school girls to design and build hands-on exhibits for the Discovery Museum. In addition, several faculty members spent time going into classrooms to act as resources for the teachers working towards implementing the engineering activities. From these things, the learning abilities and interest of the students has been something that Tufts draws upon when developing further activities and workshops for teachers.

The Tufts outreach program has grown significantly over the past nine years, and at this point runs a complex combination of programs. These include professional development opportunities, resource materials and activities for teachers to use, direct support of teachers in their classrooms working to implement engineering, and K-12 student programs. Each of these programs has been supported through external grant funding from government agencies, corporations, foundations, and individuals with specific objectives that match both the funding agencies' policy and the needs and desires of the Tufts engineering outreach program.

What can we learn from the Tufts case study, particularly in terms of sustainability? It is apparent that this program grew from individual outreach attempts into a series of varying programs that can all draw from each other making the program greater than the sum of its individual parts. For example, an activity development project for middle school engineering lessons provides an excellent resource for teachers after attending a professional development workshop. Or, watching students carry through on a project during a camp type of experience adds to the knowledge of what type of learning is truly achievable at different age levels, which can then be utilized in developing further activities and sharing with teachers in terms of reasonable learning expectations. The people working in this diverse environment continually learn and share ideas, growing the programs well beyond their individual scopes.

Conclusion

It is apparent that the benefits of a comprehensive outreach program with multiple types of projects has the makings of a sustainable system that can continue to maintain and prolong the engineering curriculum for students and teachers. The content that is developed and supported throughout all the facets of the outreach work is richer than a program that focuses on a single component, say K-12 student programs in engineering. While multiple types of projects makes a stronger program, a large part of the sustainability also falls in the financial realm. Universities that make a commitment to supporting the outreach efforts offer a key component in the longevity of the program. This commitment can be in through salary support for people working in this area, which sends a signal that the University values outreach along with research for scholarship activity. Another form of support is through space and material use for the outreach programs, administrative support, and through internal institutional grants. The payback to the institution is huge, with increased student enrollment, positive community public relations, and a natural forum for non-traditional engineering students to become involved – increasing the retention of women and minorities in the college engineering program.

Based upon the case study and considerations for institutional commitment, it is clear that the strongest, most sustainable programs will have both a diverse set of outreach programs running and some level of backing by the university hosting the outreach program. Is this the only model that is sustainable? Check back in ten years, and we'll see how it's going and what other models may have come along.

Bibliographic information

1. Webster's New World Dictionary of the American Language, Second College Edition, 1972.
2. www.prek-12engineering.org a resource for K-12 educators hosted by Tufts University
3. www.teachengineering.org a resource for engineering faculty and K-12 educators, funded by NSF

Biographical information

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Martha Cyr is a research assistant professor with the Mechanical Engineering Department at Tufts University in Medford, Massachusetts. She is also Director of the Center for Engineering Educational Outreach at Tufts University and serves on the State of Massachusetts Science and Mathematics Advisory Council. Her main area of interest is effective engineering education for all ages. Dr. Cyr received her B.S. in Mechanical Engineering from the University of New Hampshire in 1982, and her M.S. and Ph. D. in Mechanical Engineering from Worcester Polytechnic Institute in 1987 and 1997.