The Energy Engineering and Education Outreach Model and the Need to Promote ST(EE)2M

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Dr. Lynn Albers is a proponent of Hands-On Activities in the classroom and during out-of-school time programs. She believes that they complement any teaching style thereby reaching all learning styles. She just recently earned her doctorate in Mechanical Engineering from North Carolina State University where her research spanned three colleges and focused on Engineering Education; the first of its kind for NCSU. Her passions include but are not limited to Engineering Education and Energy Engineering.
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Abstract

The Energy Engineering and Education Outreach model evolved from two programs that have been successful at North Carolina State University. This paper shows some need for promoting ST(EE)$^2$M [Science, Technology, Energy Engineering, Engineering Education, and Math] and suggests that the model can be a useful tool to do so. Through the model, grades 13-16 students in traditional engineering curriculums would be exposed to energy engineering and engineering education while having the opportunity to disseminate their intellectual knowledge to K-12 students.
The Energy Engineering and Education Outreach Model

The Energy Engineering and Education Outreach Model, heretofore referred to as “the Model”, is a vision of how to promote ST(EE)^2M to K-20 students. For those unfamiliar with K-20, it represents not only primary students in grades K-12 but also undergraduates in grades 13-16 and graduates in grades 17-20. The ST(EE)^2M acronym is an metamorphosis of the familiar STEM acronym. The E has been replaced with (EE)^2 to specify energy engineering and engineering education outreach. [Science, Technology, Energy Engineering, Engineering Education, and Math]^2 There are many university programs in place supporting Science, Technology, Engineering and Math (STEM) outreach as a result of the former NSF GK-12 Outreach Program. Therefore, these programs can serve as an excellent gateways to promoting energy engineering and engineering education which can easily be incorporated. Examples of such will be presented later in the paper.

Energy engineering and engineering education are two, very important and underrepresented fields. The Model has three components as shown in Figure 1: Energy Engineering, K-12 Engineering Education Outreach, and Academics. These three areas are used to provide a well rounded and balanced set of educational experiences for undergraduates in grades 13-16 related to energy engineering and engineering education. The Model helps supplement a traditional engineering degree program that may not offer opportunities in energy engineering or engineering education to date.

Grade 13-16 undergraduates can gain valuable hands-on experience in energy engineering by pairing them with mentors in energy engineering as interns. All universities have a facilities management program that can provide mentors and can utilize undergraduates to perform energy saving tasks such as lighting audits, VAV control assessments, and meter monitoring. Using the campus as an educational lab will make the student more aware of their surroundings; show them how to apply what they learn in the lecture; and help instill a sense of pride in their alma mater hopefully creating a positive lifelong bond. Some universities also support an energy research center where the undergraduates can engage in renewable energy research and/or more energy conservation.

The K-12 Engineering Education Outreach portion of the model has a dual effect of simultaneously exposing undergraduates in grades 13-16 to engineering education and promoting ST(EE)^2M to K-12 students. Giving undergraduates the opportunity to disseminate their ST(EE)^2M intellectual knowledge to the next generation is a great learning experience. “In addition to the personal growth inherent in program participation, involvement with RAMPUP [the university’s GK-12 Outreach Program] improved fellows’ communication skills, increased their sense of community involvement, and impacted career and future plans of the undergraduate fellows.” As one, male, engineering undergraduate stated, “If you can communicate with 8-year-olds, then communicating with everyone else becomes less of a challenge”
The Model evolved from the author’s graduate experience working with two programs described later in the paper. Both programs have been successful at North Carolina State University. There were many lessons learned during the execution of each program that will prove helpful when implementing the Model.

**Need to promote ST(EE)³M**

The Wind Powering America initiative has set a goal to power 20% of the country’s energy from wind by the year 2030. In order to accomplish this goal, a workforce needs to be developed with the necessary skillsets. The National Renewable Energy Laboratory (NREL) workforce development analyses studies show that, “The greatest near-term solar and wind workforce needs include technicians and tradesmen with hands-on solar- and wind-specific experience, experienced electrical, mechanical and solar engineers, and project managers.” And in order to create this workforce a “Standardized education and training at all levels – primary school through postgraduate, industry-based training and certification, apprenticeships – are required to develop a skilled workforce to support the future expansion of wind and solar industries.”

According to the Center for Energy Workforce Development (CEWD), “an estimated 46 percent of the workforce (approx. 200,000 skilled workers) may need to be replaced by 2015, in large part due to the upcoming waves of baby boomers reaching retirement age in the coming years. At the same time, the industry is seeing a growing skill gap in applicants ranging from employability skills to academic and technical skills.” CEWD estimates a 53% potential attrition and retirement rate of engineers between 2010 and 2020 causing a need for an estimated replacement of 14,700 engineers (excluding nuclear).

According to the U.S. Department of Energy report, *Workforce Trends in the Electric Utility Industry*, the demand for electrical engineers working in the electric power generation, transmission, and distribution industry will increase to 11,113 in 2014 up from 10,280 in 2004. While the demand for power engineers due to industry growth and workplace retirement is
currently met by the supply, the report suggests that this supply is in jeopardy due to the discontinuation of university programs, which are the main path of development for power engineers.  

24 percent of bachelor’s degrees awarded in 1985 were from STEM fields. In 2009, this number dropped to 18 percent. With a declining enrollment in STEM, a lacking skilled workforce capable of supporting industries such as wind and solar, and a declining energy workforce, there is a need to expose K-20 students to the field of energy engineering. With the exception of James Madison University which has a degree program in Sustainable Engineering, most university students are forced into traditional engineering degree programs. “Students likely to major in engineering are significantly more likely than others to want to address energy (supply or demand), climate change, environmental degradation, water supply (shortages, pollution), terrorism and war, and opportunities for future generations.” So, to make engineering more enticing, one can supplement the existing, traditional engineering degree programs with opportunities in these areas through the Model. The hope is that this would increase student enrollment in engineering and help to replenish the energy workforce.

The U.S. Department of Energy report, Workforce Trends in the Electric Utility Industry, recommends fostering science and math education as well as promoting energy related careers. This is a good idea but there is always the question of how to implement this. The Model reflects incorporating K-12 Engineering Outreach which can simultaneously foster science and math education while promoting energy related careers; thus incorporating engineering education experience into an undergraduate’s curriculum.

First Program – Energy Engineering

“In short, energy efficiency is as important as conventional energy to the economy, and because of efficiency, the economy is more productive for a lower incremental cost.” ~ American Council for an Energy-Efficient Economy

According to 2009 data, the per capita energy consumption in North Carolina is 272 MMBTU per year or approximately 79,695 kWh per person. This number combines energy usage from industry, academia, government and residential sources. While 272 is below the national average of 308 MMBTU, it is still everyone’s responsibility to help reduce this number further and one of the areas where students can help is by working with the Facilities Management teams at the Institutions of the University system to reduce energy usage in academia and at Industrial Assessment Centers performing audits to reduce energy usage in industry.

The first program occurred at North Carolina State University in the Department of Mechanical and Aerospace Engineering (MAE) and is an example of the impact that undergraduates can have as interns assessing areas of energy savings in the energy efficiency and conservation sector. It was funded from the U.S. Department of Energy’s State Energy Program Workforce Development grant from federal American Recovery and Reinvestment Act money administered by the State Department of Commerce’s State Energy Office. The MAE program was one of 28 State Energy Internship Programs (SEIP) across the state totaling grants of $6,297,144.
Over a 21 month period, the MAE program accepted 62 undergraduates and interviewed twice as many primarily from Mechanical Engineering and placed them with energy mentors in the public and private sector as interns. The undergraduates interned during the semester depending on their class schedules and during the summer if applicable. Typically, the interns worked 8-15 hours per week depending on their course load. Those in their senior year with only one class, were able to log more hours. They were biweekly employees of NCSU where the grant paid for a portion of the salary while their mentor supplemented the difference. In addition to the two principal investigators, there was a program coordinator responsible for placing the interns and ensuring they were receiving quality on-the-job energy engineering experiences. One of the lessons learned was to draft an MOU – Memorandum of Understanding – as soon as possible. The MOU served to ensure the safety of the students and covered ownership of any intellectual property developed during the internship. During the program’s tenure, the undergraduates were able to perform 240 energy audits covering 8+ million square feet, recognizing 10+ million kWh in electric savings and 147 MW in demand savings.2

Participants from the 28 State Energy Internship Programs were surveyed by researchers at Appalachian State University; providing the following feedback.

“Overall, based on responses to text-entry questions, the interns reported experiences that were beneficial in two key areas: work experience and education. Interns and fellows were able to gain valuable technical/field-related experience as well as experience in business areas not available to them in the classroom setting. This included professional networking, project management, and soft skills. They were able to leverage the experience to secure other non-SEIP internships or to gain full-time employment in the industry. Interns/fellows also indicated that the program enhanced community awareness around energy issues.” 11

When the interns (n=215) were asked, “To what extent do you feel that your internship/fellowship will assist you in obtaining full-time employment after college?” 20% responded that they already did have employment as a result of the program, 26% felt it definitely will and 32% felt that it probably will assist them in obtaining full-time employment after college. The remaining 15% were not sure and 6% felt that the program probably will not or definitely will not help. 11

All participants – both interns and host employers (n=310) - were asked, “In your opinion, how important are programs like the SEIP in helping organizations find qualified employees?” 28% felt it was very important; 49% felt it was important; 13% found it neither important nor unimportant; 1% found it unimportant and 9% very unimportant 15 All participants (n=311) were asked, “Would you participate in the SEIP again?” 54% said definitely yes; 30% probably yes; 10% maybe; 5% probably not; and 1% definitely not. 11

Example of Project
Presented here is an example of the work done by two MAE interns in the SEIP who were paired with an energy mentor at the North Carolina School of Science and Mathematics (NCSSSM). They led an initiative to motivate students to conserve energy and help spread energy saving awareness by reducing the amount of electric devices that they leave on in their dormitory room.
As part of the initiative, they used Kill-A-Watt meters to measure the electric use of various items typically found in a dormitory. Table 1 shows five items using 12.74 kWh over a two week period with a computer and a surge protector using the most energy, two items that are found in most dormitory rooms. It is believed that the typical dormitory room has an average of twelve electric devices and has become an area of great potential for energy conservation measures. The two interns presented the findings in Table 1 to the NCSSSM student body to increase awareness of energy usage and to inspire behavioral changes. If students learned to turn off their computer and surge protector, this would potentially save 8.91 kWh every two weeks per dorm room.

Table 1: Device and Respective kWh Usage as measured over a Two Week Period

<table>
<thead>
<tr>
<th>Device</th>
<th>kWh Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer charger w/ computer plugged in</td>
<td>4.09</td>
</tr>
<tr>
<td>Computer charger w/ no computer plugged in</td>
<td>0.05</td>
</tr>
<tr>
<td>Surge protector</td>
<td>4.82</td>
</tr>
<tr>
<td>Printer</td>
<td>2.80</td>
</tr>
<tr>
<td>Water fountain</td>
<td>0.98</td>
</tr>
</tbody>
</table>

The timing of the initiative coincided with the electric utility bill so that the time period of February 21 to March 21 could be used to compare the electric usage in 2011 with 2012. Unfortunately, NCSSSM has multiple buildings throughout the campus which are supplied from the same utility service and not sub-metered. Because of this, it was difficult to compare building against building and measure the impact of behavioral changes. However, there was an overall 5.29% decrease in kWh per day from 23,344 in 2011 to 22,109 in 2012. Unfortunately, this could be attributed to many different factors. The overall purpose of this initiative was to raise awareness of energy usage and waste. This was a great learning experience for the interns because they learned how to coordinate the initiative, work with administration, and inspire the student body of the high school. While the impact of the behavioral changes was inconclusive it is hoped that any behavioral changes created were sustainable.

Second Program – K-12 Engineering Education Outreach

“Third Grade End of Grade scores are used to determine how much prison space will be needed in the future.” ~ Dr. Sam Houston, President and CEO of the North Carolina Science, Mathematics, and Technology Education (SMT) Center

As a society, it is time to stop being reactive and to start being proactive. Through K-12 Engineering Education outreach we can simultaneously help alleviate this problem while developing the engineers of the future who will help solve our energy problems and reduce negative impacts on the environment.

The North Carolina State University’s College of Engineering has been the recipient of two, National Science Foundation GK-12 Outreach grants totaling $4 million dollars plus half a million in supplemental funding from General Electric. During the second grant in 2005, the
second program was established. The program was a win-win-win for the three key stakeholders: university students, K-12 teachers and K-12 students. The goal of the program was to make science, technology, engineering and math (STEM) educational and fun for K-12 students by engaging them in hands-on activities centered on STEM principles. Undergraduates were encouraged to create and prepare original hands-on activities to be used in the classroom with the K-12 students. In this way, undergraduates were given experience in preparing lessons and managing classrooms, which helped improve the communication skills of engineering majors and give education majors experience before entering their student teaching semester. ³

Through this program, two successful and effective outreach programs, in which energy engineering was incorporated, were established: Family STEM Nights and Energy Clubs.

Family STEM Nights

Family STEM Nights are an opportunity for parents and their children to experience science, technology, engineering and math through hands-on activities. The goal of the events is to remove the “fear-factor” associated with STEM disciplines. Many parents want their child to learn these disciplines but they themselves do not have the skill set to support their growth. The Family STEM Nights give parents and children the chance to learn STEM disciplines together thereby empowering the parent to help their child at home.

Family STEM Nights continue through The Engineering Place at NCSU and utilize volunteers from academic and sports clubs across campus. Currently there is one Night every week at a local public elementary school however the demand for them is far greater than resources can handle.

A pilot study was performed at two elementary schools and one middle school Family STEM Night to measure their effectiveness in introducing students to science, technology, engineering and math. The same survey was given to each child before they entered the event and upon their departure to measure any change in awareness or likeability of the four disciplines. As expected, the students were aware of science, technology and math most likely through daily activities in and outside of school. However, Elementary School 1 (ES1) and Middle School 1 (MS1) had a significant (p<0.05) increase in awareness of engineering. ⁵ The results of the likeability question showed significant (p<0.05) increases in likeability for science and engineering at each of the three schools as well as a significant increase in likeability for math at the middle school. This is positive and shows that the Family STEM Nights are effective means of increasing awareness and likeability of STEM subject. Therefore it is important to continue them and provide them for all those who need it. ⁵

Energy Clubs
Energy Clubs are an out-of-school time opportunity for students in grades 3-5 to learn about renewable energy, water purification, energy conservation and recycling through hands-on activities. The students build windmills out of milk cartons, Popsicle sticks, index cards and wooden barbeque skewers as shown in Figure 2. They spend weeks implementing the engineering design process (Ask – Imagine – Plan – Create – Improve) to optimize the blade shape and quantity for maximum performance. The highlight of the club is building solar cars and competing in the Junior Solar Sprint.

The idea began with one club at one school. By the fifth year, we were operating three clubs, one for each grade level, at two schools. Students are recruited for the club through letters taken home to parents and are accepted on a first returned, first served basis. This sparked a return rate of 100 letters in two days. We could only accept the first 15 per grade level because of limited resources.

A two-year case study was performed to assess the impact of active learning during energy clubs. The assessments from the Engineering is Elementary curriculum were used and given as a pre- and post- test to the windmill activity. Overall, there were positive increases in their understanding of technology, what engineers do, the engineering design process and how to improve their windmill just from having performed the activity (Table 3). Therefore, active learning during Energy Clubs can positively affect students in grades 3-5. 4

Table 3: Percent increase in understanding the respective topics 4

<table>
<thead>
<tr>
<th>Topic</th>
<th>2009</th>
<th>2010</th>
<th>Significant?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>3%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>What engineers do</td>
<td>8%</td>
<td>8%</td>
<td>p&lt;0.05 in 2010</td>
</tr>
<tr>
<td>Design process</td>
<td>6%</td>
<td>6%</td>
<td>p&lt;0.05 in 2010</td>
</tr>
<tr>
<td>Improve a windmill</td>
<td>26%</td>
<td>16%</td>
<td>p&lt;0.05 for both years</td>
</tr>
</tbody>
</table>

Conclusion

There is a growing need for energy engineers to fill the voids created by an aging workforce. There is also the need to create a new generation of engineers that can solve the needs of a growing society with ever increasing demands for more energy. This generation of engineers won’t be specifically mechanical or electrical but some hybrid of multiple engineering disciplines. Since many universities have not evolved to provide these types of studies, there is a
need to complement an existing curriculum with energy engineering and engineering education experiences. The Model satisfies this need.

The Model provides for multiple, interdisciplinary educational experiences related to energy in order to engage and develop a student for an energy career. The Model is flexible enough that students will have research, maintenance, education and engineering experiences from which to determine their career path. The Model can also help promote energy engineering as a career choice to current university students and future ones through the Family STEM Nights and Energy Clubs. “Ultimately, the Model has the potential to infuse new energy into University programs and help develop a much needed supply of energy engineers to meet the demands of society.”

“In other words, if the engineering community can accurately communicate the connection between sustainability and engineering, we could increase the appeal of engineering for students we are not currently reaching, including those who possess desirable outcome expectations. We need students like these to develop the responses to our sustainability challenges that will shape our current and future quality of life.”

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Works Cited


15. Senator Bob Casey. STEM Education: Preparing for the Jobs of the Future. Report by the Joint Economic Committee Chairman’s Staff, April 2012.