Creating Grade 11 and 12 Curricula Guided by both Project Lead the Way and NSF GK-12

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Abstract

A new challenge for a privileged group of graduate students at Rensselaer Polytechnic Institute in the 2008-2009 academic year is to participate in an NSF GK-12 program with local high schools. The GK-12 goals are to expose STEM teachers to contemporary graduate research, raise the level of enthusiasm for pursuing undergraduate STEM majors among the high school students, and develop new curriculum with the teacher. The specific challenge to the RPI graduate fellows is to add games, scenario building, international comparisons, and authentic research to the STEM instructional tools. This presentation will discuss Dale Weber's experience as an RPI graduate student participating in our first year with a GK-12 program and his unique task among the participants to reach GK-12 goals within the framework of Project Lead the Way (PLTW). Typically, PLTW courses are designed by a central committee and disseminated to teachers with complete curriculum; supply lists; and PowerPoint lectures. His exposure is with the junior level course, Principles of Engineering (POE), and the senior level course, Engineering Design and Development (EDD). In POE, the George Reluzco (the teacher) and Dale developed an international energy survey to expose students to the energy production and transportation technology around the world, to gauge the balance of energy needs with environmental protection in different nations, and to get a sense of how each country's university-level research is melding with green entrepreneurial ship to put that country on the cutting edge. The EDD class is a yearlong project-based design course and the GK-12 goals have become manifest in providing support for students to modernize their projects and pursue contemporary problems. Two keynote projects this year are studies of pantothenic acid as an

acne solution and conversion of a gasoline engine to run on hydrogen gas provided by onboard hydrolysis of tap water.

Introduction

Today, it is clear that those trained in science, technology, engineering, and mathematics (STEM) will play a significant role in maintaining the leadership role of the United States in this increasingly competitive era. Employment in science and engineering is growing at a rate triple that of other occupations at 3.6% annually, yet the number of undergraduate degrees in these fields is only growing at 1.5%. This disparity may have a number of social, economic, or political causes, but with 26% of science and engineering degree holders in the labor force over the age of 50 there is a dire need to regain the interest of high school students in these fields[1].

There are several programs from the private and public sectors that are trying to increase high school level enthusiasm in STEM subjects. One such program from the private sector is Project Lead the Way (PLTW) and one from the public sector is the NSF's "Graduate Teaching Fellows in K-12 Education (GK-12)" program. This paper will compare and contrast the goals of these two programs, and from the perspective of a GK-12 fellow coming into PLTW courses, discuss the experience of participating in both programs simultaneously.

GK-12

Rensselaer Polytechnic Institute has been involved with the NSF GK-12 program since August 2008. The local program has taken on the subtitle "Discovery-based Activities in Energy and the Environment (DAEE)." There are ten graduate fellows from an array of science and engineering programs working with STEM teachers at five high schools in the capital region[2]. Each fellow's daily experience is unique because they work in all different grade levels and types of STEM classes and have unique external constraints on their interjection into the curriculum, i.e. classes are geared towards a state issued subject exam (Regents exam) or that need to comply with PTLW have less flexibility than those that do not. It is the challenge, then, of the fellows to add games, scenario building, international comparisons, and authentic research to each STEM teacher's instructional tools given their unique circumstances.

The prime directives of GK-12 are to get graduate students from local colleges and universities into nearby high school STEM classrooms to develop new lessons, familiarize the teacher with university level research, and promote undergraduate majors to the students. The graduate student fellows are encouraged to bring their own research and related resources into the classroom. These resources may include textbooks, research journals, equipment, or facilities, e.g. campus wind tunnel. Additionally, participating teachers will visit the graduate student laboratories this summer and have the opportunity to engage in research along with their fellow.

Project Lead the Way

Project Lead the Way (PLTW) began in twelve high schools in New York in 1997 to offer a curriculum centered on making students more familiar with applied engineering and modern technology. The program has expanded to middle and high schools and is used at over 3,000 schools nationwide[3]. PLTW's goal is to increase the number, quality, and diversity of engineers produced by the educational systems in the United States[4]. There are eight high school level courses offered to participating schools, three foundation courses: Introduction to Engineering Design, Principles of Engineering, and Digital Electronics; four specialization courses: Aerospace Engineering, Biotechnical Engineering, Civil Engineering and Architecture, and Computer Integrated Manufacturing; and a capstone course: Engineering Design and Development.

Program Comparisons

The nature and scope of the PLTW and GK-12 programs are very different with some overlapping ambitions. Both programs have a similar genesis as educators and professionals respond to the projected glut of American engineers within this generation. The PTLW solution is to replace the school's engineering programs, if any existed, with a franchised curriculum. Participating teachers and guidance counselors have mandatory training requirements, but are also to provide feedback to the planning committee. The central organization is responsible for producing advertising materials, setting teacher and student performance standards, and tracking the college and career outcomes of its graduates.

The NSF GK-12 program, on the other hand, aims to make college STEM studies less intimidating to the students by injecting graduate students into the classroom; a great deal of whom are less than ten years out of high school themselves. The graduate fellows draw on their recent high school and undergraduate experiences to work with the teacher to create fresh and effective lessons.

Both programs emphasize the connection between engineering choices and their environmental impact. There is also the shared goal of motivating the high school students to seek an undergraduate education in an engineering field, but by different means. The incentive for STEM bachelor's degrees in PLTW is high-demand, high-impact career potential; whereas in GK-12 it is graduate school and cutting edge research. Project Lead the Way is very successful in increasing the presence of women and minorities in STEM education. The GK-12 program, at least at RPI, has not yet shown gains in STEM diversity, but there is great potential for these kinds of changes as the program builds relationships with more nearby high schools.

Mohonasen High School

Mohonasen High School (MHS) is located in Schenectady, NY, 15 miles west of Albany. The 1160 student public high school is in the Rotterdam-Mohonasen Central School district. Of the 2002 cohort, 75% graduated in four years and 88% of those students graduated with a Regents Diploma. The student population is primarily white and 13% of students participate in the free lunch program[5].

Seven of the eight PLTW engineering courses are offered at Mohonasen, i.e. Biotechnical Engineering is not offered. The GK-12 fellow assigned to MHS, Dale Weber, works in two PLTW courses taught by George Reluzco: Principles of Engineering (POE) and Engineering Design and Development. (EDD).

Principles of Engineering

Principles of Engineering is taught at MHS as a junior level course in two sections. The typical lesson sequence is listed in Table 1.

Table 1 Typical *Principles of Engineering* Curriculum at MHS

1. Engineering Majors, Colleges and Careers
2. Bridge and Truss Engineering
3. Bridge Building with competition in ASEE E-Week
4. Materials Science
5. Tensile Testing
6. Centroids and Moments
7. Simple Machines
8. Egg Launch
9. Rube Goldberg Device

This intended itinerary does not meet all the stated objectives of both PLTW and GK-12, namely the common goal of considering the impact of engineering technology on the environment. Apropos of recent events, e.g. $4.00/gal regular gasoline, a lesson was developed to explore the global breadth of energy and related technology. The lesson, "Energy, Environment, and Technology," was delivered between lessons 1 and 2 in the sequence in Table 1. The unit was broken into two phases and required ten 80-minute class periods.

The project goals were given to the students upon the introduction of the unit and are as follows:

- Become an expert on the energy portfolio of the country of your choice
- Gain familiarity with the economic ties to energy in this country

- Become fluent in the interactions of energy with the environment
- Survey the technology used in energy production, storage, and distribution

In the first phase, students use the internet to find information on import/export ratios of energy-related raw materials; energy production methods from raw materials; international energy trading and economics; and environmental consequences and treaties resulting from the country's energy choices. The students also had to investigate the natural resources available to the country and estimate changes to energy profile of the country if these resources found better utilization. Lastly, the students were challenged to conclude Phase I by generating three questions based on their research and answering them.

The research involved in Phase II is strictly geared towards becoming familiar with the technology used in energy production. The students are to select a piece of equipment or process that is currently used for energy production in their country; review patents in online databases; and identify the terms, with units, of three relevant equations. The students are asked to look at the prevalence of their chosen piece of technology and estimate its future application by browsing the current energy technology research in their country.

As an example of the Phase I results of the project, here are excerpts of the findings from the group that investigated Germany[6]:

- Lack of resources led Germany to become a world leader in the development of renewable energy
- Largest producer of biodiesel fuels and largest generator of electricity from wind
- Renewable energy accounted for 5.8% of energy consumption in 2000 and has climbed to over 14% by 2007. Goal is to reach 27% by 2020.
- In 2001, $12.7 billion was invested in renewable energy

Similarly, two excerpts from Phase II research on solar technology in Spain demonstrate that the students are exposed to alternative energy technologies outside of the United States, the footprint of the technology in the country, the advantages and disadvantages of the technology, and the companies that are advancing the technology[7]:

> Spanish companies and research centers are taking the lead in the recent revival of concentrated solar power, as expanses of mirrors are being assembled around the country for concentrated solar plants. At the same time, Spanish companies are also investing in huge photovoltaic fields, as companies dramatically increase production of PV panels and investigate the next generation of PV. Spain is already fourth in the world in its use of solar power, and second in Europe behind Germany, with more than 120 MW in about 8300 installations of PV. Within only the past ten years, the number of companies working in solar energy has leapt from a couple dozen to a few hundred. Southern Spain, a region known the world over for its abundant sun and scarce rain, provides an ideal landscape for solar thermal power. Solar thermal power, also known as concentrating solar, works by utilizing the heat of the sun (unlike PV panels, which work on the principle of the movement of electrons between layers when the sun strikes the materials). Concentrated solar has until recently cost nearly double that of traditional natural gas or coal power plants, and it only works effectively on a large power-plant scale.

The second:

> ACCIONA SA is a multi-billion dollar energy company that is headquartered in Spain. It has been on a team of companies that are designing new forms of solar and other renewable energies. One development that they made was Concentrated Solar power. In solar energy, panels are typically placed at certain angles to obtain the best sunlight. However, in concentrated solar, solar panels are strategically placed to obtain the most amount of sunlight while still reflecting the light to a single tower that gathers all the light in. This single tower then transmits the energy to a water depot and the heat vaporizes the water, creating high-pressure steam. This high-pressure steam then enters a turbine, which powers a generator where it produces usable electricity. After the process is over, the steam goes into a condenser, where it turns it back into water, to restart the process.

Engineering Development and Design

Engineering Development and Design (EDD) is PTLW's senior level capstone course where students complete all steps of a design project from problem identification through prototype construction. This course is intended to include the participation of real-world mentors from local colleges and industry. At MHS, many of the mentors come from General Electric in nearby Niskayuna, NY. The student teams are required to send their mentors a weekly email and to present to the panel of mentors three times over the course of the year.

Within the PLTW sequence, the students have completed smaller design projects such as bridge building, egg launch, and the Rube Goldberg device in POE, but in EDD the project is more open-ended. The complete design process is outlined in Table 2 and lectures are only given for design steps that have not been introduced in previous courses.

Table 2 *Engineering Development and Design* Project Outline

1. Problem Identification
2. Problem Statement
3. Design Brief
4. Customer Identification and Survey
5. Patent Review
6. Expert Identification
7. Brainstorming/Design Matrix
8. Initial Cost Estimate
9. Project Scheduling
10. Hand Sketches
11. Computer Drawings
12. Revised Cost Estimate
13. Prototype Construction
14. Exit Survey

The project objective is to improve a product or simplify a task and end with a prototype. Students brainstorm, as a class, to generate project ideas and then develop a matrix to quantify the impact of the suggested projects. Most students choose projects from the sphere of their school lives such as wrestling mat storage; modernizing the teacher supply cart; and installing a HAM radio antenna for the middle school. Two projects undertaken this year are broader in scope and explore problems in technology current events: the "Acne Solution" and the "Hydrocar."

The origin of the "Acne Solution" project is sign of the times: the students wanted to investigate anti-acne claims attributed to vitamin B5 (pantothenic acid) that are commonly posted, without scientific support, in teen-oriented internet discussion forums. The social impact of internet technology became apparent to the instructors when the students initially treated the online claims as fact. The starkest of the claims about B5 acne treatment is the dosage: 1,000 times the recommended daily allowance (5-10mg/day vs. 10g/day)[8,9]. This dichotomy of sources required adding a design step for this project: separate myths from facts in the background information. Through the GK-12 fellow, this student team was provided access to the research library and journals at RPI to incorporate peer-reviewed research conclusions into their work.

To get answers to their questions about B5 as an acne treatment, the industrial mentor worked with the team to develop a testable hypothesis and the GK-12 fellow helped to design experiments. The "Acne Solution" project is unique in the class because the product design and testing required the students to learn some basic facts about biofilms and microbiology. Coincidentally, the fusion of engineering and biological systems is the future direction of new course development in PLTW. It is also a theme of the GK-12 fellow's graduate research; therefore this group's project provided an excellent opportunity to bring graduate research techniques and equipment into the classroom. The student's preliminary research results are shown in Figure 1 where they are testing common acne treatments and B5 on facial bacteria grown on agar plates.

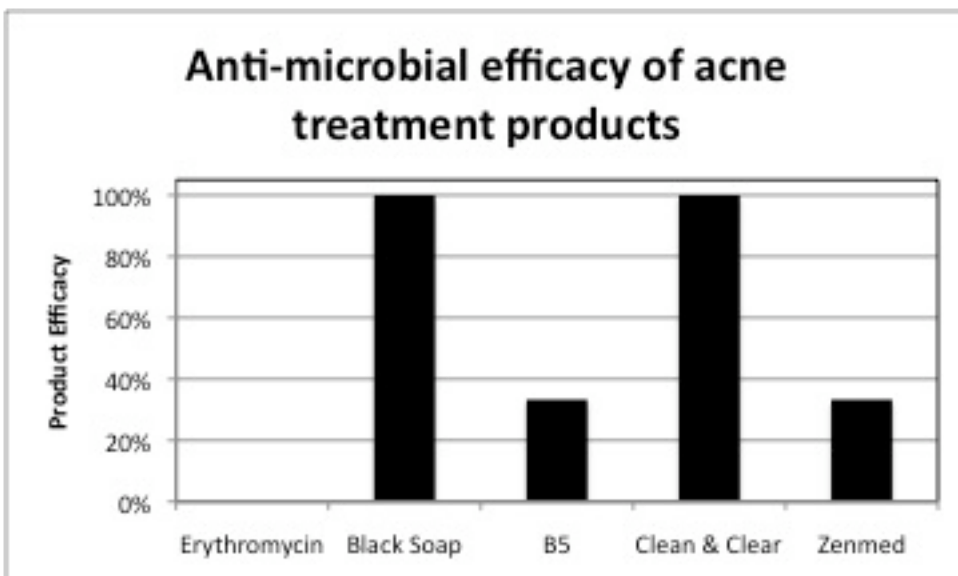

Figure 1 "Acne Solution" team's initial findings about acne products and facial bacteria

The "Hydrocar" project is another example of successful integration of the PLTW and GK-12 programs. These students in this team are all automobile enthusiasts and follow alternative energy current events closely. Their interest was in converting a traditional internal combustion engine to run directly off of hydrogen gas produced onboard by electrolysis of tap water. The

GK-12 fellow brought to the team's attention a seminar at RPI addressing engineering topics about hydrogen as a future fuel, which they attended and asked questions.

To develop the hydrolysis unit, the team ran a series of experiments decomposing water with an array of electrode materials and dimensions. The GK-12 fellow provided ideas and materials for the hydrogen gas evolution rate measurement setup and the industrial mentor provided the students with an optimization algorithm for their data. The results of this analysis for solid copper rod electrodes are shown in Figure 2, where the length and diameter dimensions are inches. Accordingly, the students are proceeding with the prototype development using 1.25" dia. x 2.75" long electrodes.

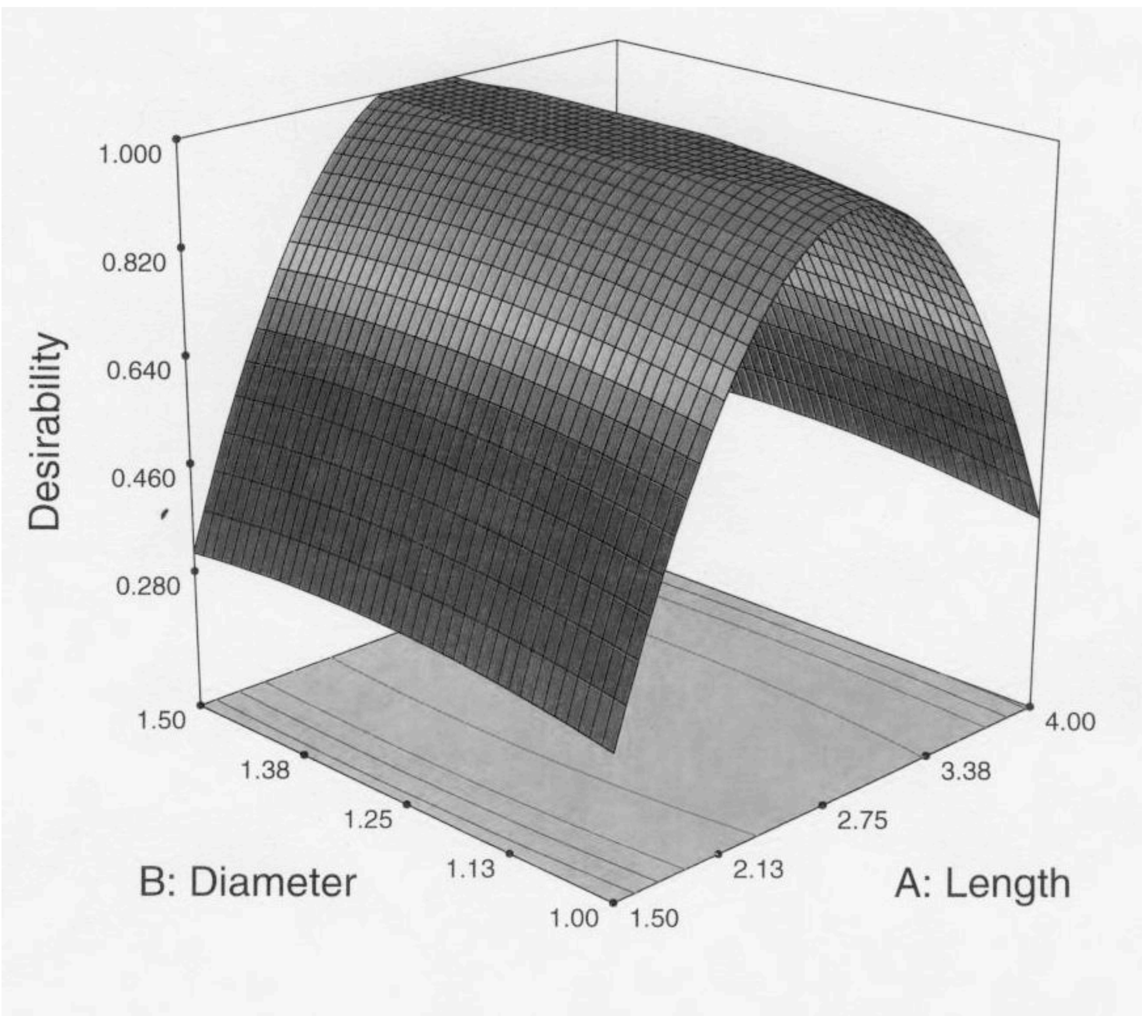

Figure 2 Results of "Hydrocar" team's electrode optimization analysis

Future Outlook

Each Project Lead the Way class at Mohonasen High School that the NSF GK-12 fellow worked with had different obstacles towards integration. The prescribed Principles of Engineering lesson schedule has limited empty space for new lessons. In addition, this class has a final exam, written by the central PLTW organization, that may qualify students for college credit which limits flexibility in lesson planning. The difficulties integrating GK-12 themes into Engineering Design and Development are almost the opposite, i.e. the distributed nature of a year long project course with few lectures puts the onus on the fellow to "teach" the teams individually. It is obviously harder and more time consuming for the fellow to scale-up his efforts in this fashion, however the impact to the student is more profound.

It is important to note that the GK-12 fellow did not begin work with MHS until six weeks into the school year. In coming years, the difficulty integrating GK-12 and POE can be minimized by better communication and preparation before classes begin. As an inaugural year of the GK-12 program in the area, future high school/RPI pairings will only gain in effectiveness as both sides in the collaboration learn from the experience.

Participant Biographies:

George Reluzco

George Reluzco teaches pre-engineering classes at Mohonasen High School in Rotterdam, NY. He has been teaching for 9 years. He currently teaches three Project Lead the Way courses to students in grades 10 through 12: Aerospace Engineering, Principles of Engineering and Engineering Design & Development. George is also a Master Teacher for PLTW's Aerospace Engineering course.

George obtained his teaching certification in Technology Education from the College of St. Rose. He earned a B.S. degree in Mechanical Engineering from the City College of New York and a Master of Science degree in Mechanical Engineering from the University of Vermont. Prior to teaching, George worked for GE as a mechanical engineer designing components for armament systems, steam turbines and gas turbines. In 2008 he was selected as a Times Union teacher scholar. He is an advisor to the Team America Rocketry Challenge club.

Dale Weber

Dale is from the San Francisco Bay Area in Northern California and did his undergraduate studies at UC Berkeley in Chemical Engineering and Materials Science. Dale is currently a graduate student in the Howard P. Isermann Department of Chemical and Biological Engineering at Rensselaer Polytechnic Institute under the supervision of Prof. B. Wayne Bequette.

He did a nine month co-op at the soon to be named George W. Bush Sewage Treatment Plant in San Francisco and a three month internship in Finland. These experiences opened his eyes as to how modern industry can be operated while still being green and environmentally responsible. Dale studies the production of composite materials that are largely composed of bacterial cellulose. The materials are produced as the bacteria grow around suspended filler-materials, like silica gel, in the reactor. This is a green alternative to traditional methods of cellulose-based materials production, which require the use of harsh solvents. This technology can also be fed by recycled organic materials since bacterial cellulose can be produced by *Acetobacter xylinum* from a number of simple carbohydrate sources - which can be obtained cheaply from farm and fruit wastes.   Dale's hobbies are hiking, skiing, and water polo.

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