

Engineering Ambassadors in the High School Classroom

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Abstract

Students and faculty within the School of Engineering and the Neag School of Education at the University of Connecticut have initiated a program, with the support of the National Science Foundation, to introduce core engineering concepts to select high school students in the State of Connecticut. This program, entitled the Galileo Project, is an extension of the university's already-successful da Vinci Project, now entering its fourth year. This paper describes the goals and objectives of the program and documents progress made during the first nine months.

Introduction

The University of Connecticut School of Engineering, in partnership with the UCONN Neag School of Education, selected local school districts, the Greater Hartford Academy for Math and Science, and local industry, received an award from the National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program¹ to develop and implement an innovative, comprehensive, affordable, and accessible program to integrate engineering into the secondary school curriculum. This program, called the "Galileo Project" seeks to: 1) make college engineering programs accessible to the widest possible range of students, including those from underrepresented groups, 2) instill a strong sense of commitment to and appreciation for education among participating Fellows, and 3) expose teachers to the tremendous challenges, rewards and opportunities that are implicit in engineering education and practice. The proposed program builds upon years of highly successful outreach activities to K-12 teachers and students undertaken by UCONN.

History of Commitment to Engineering Education

UCONN is one of over 75 institutions receiving funding under the three-year-old NSF GK-12 program to promote and improve education in science, math and engineering. The UCONN program, colloquially entitled The Galileo Project, is an outgrowth and extension of a program established by the School of Engineering in 1999 and now entering its fourth year of operation. That program, called the da Vinci Project was designed to introduce math and science teachers to core engineering concepts. By allowing these teachers to work side-by-side with engineers in academia and industry, they would become empowered to bring engineering into the classroom, to discuss engineering as a career option, and act as a guide for those students interested in engineering. It was hoped that the term, 'engineering' would enter the lexicon of secondary

education.

Participants spend a week in a civil, mechanical, chemical, electrical or materials engineering laboratory learning fundamental concepts of engineering, and developing hands-on projects they could use as practical instructional material in their classrooms. They tour laboratories within the School of Engineering to learn of some of the cutting edge technology under development, and also tour various university engineering systems such as the wastewater treatment plant. In addition, they participate in discussions with engineers from industry and the university to explore how the three groups could best work together to serve the needs of a student considering engineering as a career. As part of the program, the participants are eligible to earn four Continuing Education Units (CEUs) and are paid a stipend.

The teachers leave the workshop convinced of the importance of including engineering in their curriculum, whether math, science or technology. To date, over 125 teachers have participated in the da Vinci Project, representing 45 school districts from throughout the United States. The experiences of the da Vinci Project workshop demonstrated the appropriateness of beginning to affect curricular change through teacher education and suggested several additional avenues for integrating pre-engineering in a meaningful way in secondary school curricula without necessitating replacing or adding numerous additional courses.

Based on the successes enjoyed by the da Vinci Project, on other outreach activities at UCONN (the Bridge Program, E2K, Multiply Your Options, the Connecticut Invention Convention: access information at <http://www.engr.uconn.edu>), and in part on models of several other national initiatives for engineering education (PLTW², JETS³, other GK12 programs^{4,5}) the Galileo Project will proceed along several complementary fronts in parallel:

- 1) Development and refinement of pre-engineering course modules for high school students in a variety of core engineering areas;
- 2) Training of engineering graduate and advanced undergraduate students (called Galileo Ambassadors) to assist high school teachers in delivering and implementing the modules mentioned in (1) above, as well as to be a resource (to students and teachers) in engineering, science and math education;
- 3) Sponsorship of a capstone "Engineering Competition" between the participating school districts where each team, under the mentorship of Ambassadors, is given the same engineering problem to solve;
- 4) Designating several two-semester Senior Design Projects in the School of Engineering to education intensive projects in which selected high school students participate as team members;
- 5) Training of in-career high school SMET teachers in engineering education, primarily through participation in a one - week summer institute and bi-monthly workshops alongside engineering Graduate Fellows;
- 6) Establishment of a Galileo virtual engineering community using computer infrastructure resources at the University of Connecticut as a major venue for project planning, communication and resource/experience sharing for all participants in this project and the education community in general;
- 7) Development of a "Master of Engineering Education" degree to provide engineering graduate students interested in exploring teaching careers, or secondary school teachers, in-depth preparation in engineering and discipline-specific pedagogy; and
- 8) Ongoing assessments of the proposed Galileo Project to evaluate the effectiveness of

the approach, to develop methods to transfer the proposed curriculum and infrastructure elements to other states, and to assure viability of the Galileo Project following the expiration of grant funding.

First-Year Activities: Galileo Ambassadors

To date, eight graduate and one undergraduate Galileo Ambassadors have been recruited and include six Ph.D. candidates, two M.Sc. candidates, and one undergraduate senior who intends to continue in the program as a M.Sc. candidate post-graduation. These fellows represent the Departments of Mechanical, Civil and Environmental, Electrical and Systems, and Computer Science and Engineering, as well as Biomedical Engineering. The students were selected based, in part, on their stated commitment to public education, both currently and in the future. Some already have experience either as high school science teachers, or in various K-12 outreach programs already offered by the School of Engineering. The main factors in the selection criteria are as follows:

- Ambassadors will be good communicators,
- Ambassadors will be good listeners,
- Ambassadors should demonstrate a genuine interest in education,
- Ambassadors will possess strong and attractive interpersonal relations skills,
- Ambassadors will have dynamic, engaging and lively personalities,
- Ambassadors will be creative,
- Ambassadors will have a strong understanding of basic engineering concepts,
- Ambassadors will have solid interest and skills in experimental work,
- Ambassadors will represent a diverse population that includes women and minorities.

The Fellows are required to take 6 graduate credits within the School of Education-the first course will be offered in the Spring, 2003 semester. It is listed as EDCI 326, "Teaching Science and Engineering in Middle and Secondary School Classrooms", and will be taught at the Greater Hartford Academy for Math and Science, a partner in the grant and part of the ground-breaking "Hartford Learning Corridor" conceived by Evan Dobelle, past president of Trinity College. Fellows will also be encouraged to participate in a methods and assessment course as their second education requirement.

The Fellows have been intensively involved in the development of engineering "modules", curricular materials that will help to introduce core engineering concepts into a variety of classrooms across varied disciplines. This program will rely primarily on a hands-on, inquiry based approach to teaching fundamental engineering principles through the development of flexible modules that can be integrated into existing physics, science, computer science, and mathematics courses. Experiments or case studies in the core engineering areas, represented by departments within the School of Engineering cited above, will be developed by a team consisting of UCONN faculty, staff and Graduate Fellows and will draw upon existing state⁶ and national⁷ frameworks as guides to curriculum content. Fellows, in coordination with teachers, will be in charge of delivering these modules to high school students and train them in the science and engineering background specifically needed for these modules.

The majority of the module experiments will be designed to complement and enhance concepts

already being taught in existing high school classes and be age- and ability-appropriate for high school students. They will also take into account the limited material and financial resources found in many school districts. The modules will be designed primarily as laboratory contact time, supplemented with lectures as necessary to convey theoretical background material central to the understanding of the experiments' framework. The design of the modules will be such that they may be incorporated into a traditional schedule or into a block schedule. They will clearly demonstrate the open-ended nature of engineering problem solving and the implied consequences of decision making by the students in modeling and design process. In these modules, modeling and analysis will require basic understanding of the scientific fundamentals covered in a traditional science curriculum. However, it will be demonstrated that the application of these principals (as well as the decision on which principals apply) can be demanding, challenging and rewarding. Particular emphasis will be placed on communications (oral and written), process design and process writing. But most of all, these modules will be designed to create relevant, exciting and lively experiences for students.

Recognizing that individual teachers, departments, and high schools may find it difficult and challenging to make changes in existing curriculum, the modules will be designed to minimize the need for such changes. UCONN faculty, staff and Galileo Ambassadors will work with participating districts to infuse the new engineering modules into existing coursework by reviewing course content with the classroom teacher and suggesting means to add the new materials with a minimum of disruption.

The modules include the following areas of specialization:

- Design of a Multi-band Stereo Equalizer,
- Robotic Design Module using Shape Memory Alloys,
- Understanding Proton Exchange Membrane Fuel Cells,
- The LaPlace Transform and its Application to System Modeling,
- Design and Construction of a Sound-Activated Switch,
- Reverse Engineering of a Murder-Tale of a Missing Cat,
- Basics of Mechanism Design,
- Design and Engineering of Musical Instruments,
- Forensic Engineering of Automobile Accidents,
- Design and Construction of a Hydraulic Robotic Arm,
- Design and Construction of a Telescope,
- Design and Construction of an EKG Sensing Circuit,
- Water Management and Wastewater Treatment.

The development of each module will include full historical, design and mathematical documentation as well as all necessary background material to facilitate transfer of curriculum to classrooms not directly participating in the program.

In addition to these modules, the Fellows and Project PI's have engaged in lengthy and critical discussions on engineering and scientific research as social endeavors, and the similarities and differences inherent in both disciplines. These discussions have led to the development of a (position) paper (see the accompanying paper #2003-1133) that will be incorporated into the program as a point of emphasis.

First-Year Activities: Participating School Districts

The Project is designed to support the participation of up to seven school districts from throughout Connecticut, and the first months of the program were involved with soliciting and selecting those districts. School districts were approached based on several guidelines. They included the willingness of the districts to support the goals and initiatives of the program, the desire to include engineering as part of the core science/math/technology curriculum, a needs-assessment of the district based on demographics to ensure the program was inclusive, and prior participation in UCONN School of Engineering outreach activities. The districts selected include two large urban/suburban and one (adjacent to the UCONN campus) mid-sized high school, all three demographically diverse. The other four high schools vary in size from small to medium and are located rurally, two from economically challenged farm communities. Each district supports the participation of three teachers representing a variety of disciplines (math, science, technology, computers) and academic levels (honors, college prep, and general education).

At the onset of the project, Galileo Ambassadors participated in a one-week engineering workshop alongside the participating teachers, based on the pilot da Vinci program. Monthly follow-up workshops during the academic year are scheduled. The participating school districts are required, as part of their agreement with UCONN, to provide Professional Development release time for their teachers. These workshops will be designed to achieve three main objectives:

1. To create a sense of camaraderie and partnership between teachers and the Ambassadors assigned to them:
 - a. Teachers will develop an appreciation for the knowledge and skill of the Ambassadors as engineers,
 - b. Ambassadors will develop respect for teachers and will accept them as mentors,
 - c. Ambassadors will develop an appreciation for challenges that face teachers,
 - d. Teachers will develop an appreciation for the "real world" impact of engineering.
2. To familiarize the teachers and the Ambassadors with the engineering modules and solicit their active participation in finalizing the modules:
 - a. To solidify their understanding of the engineering and scientific principles involved,
 - b. To introduce them to the hardware and experimental settings involved in each module,
 - c. To get them engaged in actively shaping and customizing the modules for each school or classroom.
3. To train the Ambassadors on teaching methodologies and skills:
 - a. To learn how to manage classrooms,
 - b. To learn how to motivate students,
 - c. To learn how to instill good work habits and engineering ethics in students,
 - d. To learn the fundamentals of a constructivist approach to teaching.

The participants will also take part in discussions about the field of engineering in general, educational requirements and prerequisites for post-secondary education, the various disciplines within engineering, and the options available to students in making engineering a career choice.

Fellows will be assigned to the same school district for the duration of the project in order to achieve a sense of continuity within the school, with the teachers, and with students. However, the Fellows will also visit other participating schools to lend their particular expertise as needed.

Project Assessment to Date

Assessment to date has been largely anecdotal and the result of meetings, workshops and conversations amongst Project participants. Fellows and project managers meet weekly to discuss ongoing progress of module development, as well as program operation and management issues and their work in the classrooms. All project participants meet on a monthly basis to review ongoing development of the curricular modules and to discuss the operation and implementation of the program, including the use of the concept of “Understanding by Design” for curriculum development and “Critical Friends” for review and assessment. In the Spring, 2003 semester, the School of Education will develop a critical assessment program to monitor the impact of the program on the participating districts.

Concluding Remarks-What the Future Will Bring

During the first nine months of the program, the fellows have been visiting their host schools on a regular basis to allow the students to become familiar and comfortable with their presence. In most cases, the Fellows have already begun to assist the classroom teachers in the presentation of certain engineering concepts. It is estimated that the Fellows have had a direct impact on approximately 1,200 students in the classroom. The Project Director has visited all seven schools and observed the Fellows in their classroom environments. As well, he has made formal presentations to the district Boards of Education in an effort to keep the community informed and involved as the Project develops and matures.

As the modules become more fully developed in scope and detail during the Spring, 2003 semester, the Fellows will begin to teach certain aspects of the modules to determine their appropriateness for the classroom. It is anticipated that the full program of modules will be available by the Fall, 2003 semester.

Design and construction of the virtual engineering community through the Galileo website (<http://www.uconngalileo.engr.uconn.edu>) has begun and development of the site should accelerate over the next several months with the employment of a graphic design specialist. Discussions have been initiated between the Schools of Engineering and Education to develop and implement a Masters of Engineering Education, with the possibility of a Certification in Engineering Education at the Connecticut State Department of Education. This may rapidly become a necessity-Massachusetts last year altered its state education frameworks to include a mandate to teach engineering K-12, and Connecticut will shortly release its new frameworks, also mandating engineering education.

The implementation of this program is viewed as a dynamic process, and it is expected that ongoing evaluation and formative assessment will drive continued program improvement.

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Biographical Information

Robert F. Vieth is the Project Director for the Galileo Project, and a staff member of the School of Engineering. He recently resigned as a research scientist after 25 years at UCONN and is pursuing a Ph.D. in science education at that institution. He is a Fellow of the Connecticut Academy for Education in Math, Science and Technology.

Kazem Kazerouni is a Professor of Mechanical Engineering at UCONN since 1995. His research interests include mechanical design, robotics, chaos theory, and engineering education. He served as Associate Editor of the ASME Journal of Mechanical design, 1994-1999, and is a Fellow of ASME.