CONTENTS
Program Descriptions

The program descriptions are listed in the order of the corresponding session on the agenda.
The session title appears in parentheses when different from the program description title.

Design Squad Nation *(Design Squad: Inspiring a New Generation of Engineers)* 1

Engineering High School Biology into the 21st Century 3

Engineer Your World: Engineering Design and Problem Solving for High Schools 5

Integrating Engineering and Literacy (IEL) 7

Society's Grand Challenges for Engineering as a Context for Middle School STEM Instruction *(Making a Difference in the World: Engineering in Middle School Math and Science Classrooms)* 9

Engineering is Elementary Engineering and Technology Lessons for Children Problem Solving, Inquiry, and Innovation *(What Does It Mean to "Engineer" in Engineering is Elementary?)* 11

CAPSULE: How to Use Engineering-Based Learning (EBL) in High School *(CAPSULE: How to Use Engineering-Based Learning (EBL) in High School STEM Teaching)* 13

Elementary Engineering Teacher Professional Development: Initiation to Integration 15

Engaging Youth through Engineering (EYE) Modules: Integrating and Bringing Relevance to Core Middle Grades Mathematics and Science Content 17

Implementing K–12 Engineering Standards through STEM Integration 19

Science Learning through Engineering Design (SLED) *(Learning Science Through Engineering Design: An Effective Approach to STEM Integration at the Elementary School Level)* 21

Project MINDSET: An Engineering Modeling Approach to Teaching High School Mathematics *(Mathematics Instruction Using Decision Science and Engineering Tools)* 23

Biomimetic MicroElectronic Systems Engineering Research Center *(K–12 and Higher Education: Why Collaboration Is Vital)* 25

NSF Engineering Research Center for Biorenewable Chemicals (CBiRC) Pre-College Education Program *(K–12 and Higher Education: Why Collaboration Is Vital)* 27

Design Squad Nation

Background

Design Squad is an NSF-funded digital hub for middle school children that includes (1) television episodes and short videos streamed on pbskids.org, (2) an online community of young engineers, and (3) hands-on engineering activities. Designed to increase children's understanding of engineering, the Emmy and Peabody Award–winning television series follows two teams of teens as they design and build projects for real-world clients—from constructing cardboard furniture for IKEA to designing peanut butter makers for a women's collective in Haiti.

Its spin-off television series, *Design Squad Nation*, showcases engineer co-hosts Judy and Adam as they travel across the country, working side by side with teens to turn their dreams into reality through engineering. Tackling an array of engineering projects—including a water-saving toilet and a human-powered flying machine—the show aims to get kids thinking about the creativity and fun involved in engineering projects. Online, Design Squad's Emmy Award-winning website at pbskids.org/designsquad provides kids with one of the only places on the Web where they can safely share their engineering ideas, sketches, and photos with other kids. And offline, Design Squad's 69 hands-on engineering activities (available in the Parents and Educators section of the website) enable kids to exercise their design skills, tapping into their ingenuity and teaching them to think like engineers.

A powerful introduction to engineering for a middle school age group, Design Squad combines real-world engineering problems with simple, easily accessible materials, allowing students to imagine themselves as engineers and engage in engineering endeavors. More specifically, Design Squad:

- features challenges that are open-ended, are focused on improving the world by meeting people's needs, and provide the experiential basis for understanding science concepts;
- gets kids comfortable with the design process and bolsters their confidence in designing and building; and
- provides formal and informal educators with resources (in-person trainings and online tutorials) for introducing the design process and ways to teach hands-on, open-ended challenges.

Concurrent with production of Design Squad's digital hub, WGBH, Purdue University, and Concord Evaluation Group are collaborating on the NSF-funded Informal Pathways to Engineering (IPE) project. IPE is a research study designed to document the ways in which informal engineering programs support, or fail to support, children's engineering-related interests, outcome expectations, and self-efficacy. It is also exploring how informal programs motivate children to learn about engineering, as well as how these programs encourage children to seek out engineering activities. By enriching and expanding the assets of Design Squad, while carefully researching children's informal engineering experiences, the IPE study is breaking new ground in the quest to understand how to create pathways that encourage children to ultimately pursue engineering careers.

Documented Results

Evaluations have confirmed the project's impact on children's attitudes towards and knowledge of engineering. A summative evaluation demonstrated that after watching only four episodes, students had a strong understanding of the featured engineering concepts, increased their design process skills, and changed their stereotypes about engineering—for the better. Even more impressive, nearly two-thirds of the children were interested in participating in an engineering afterschool program after viewing, compared with just below one-third prior to viewing (GRG, 2008). Subsequent evaluation found that children exposed to Design Squad demonstrated significant gains in their understanding of key science concepts and improved their attitudes about engineering stereotypes as compared to a control group (CEG, 2010).

Application

Since its premiere in 2007, Design Squad has produced 46 half-hour episodes, 24 short career profiles of engineers, and 62 animations of STEM concepts. The project has launched an online community with 118,000 monthly visits and over 74,000 engineering project ideas submitted by members; two Facebook pages (with more than 11,000 fans); an active Twitter feed (with close to 1,000 followers); and a YouTube channel (with more than 500,000 views of its videos). Offline, Design Squad has conducted 736 trainings, workshops, and events for 250,948 engineers, educators, kids, and families across the country. More than 8,000 programs have used Design Squad's educational materials, which include seven educators' guides, an online introduction to engineering professional development course for the Massachusetts Department of Education, an online workshop in partnership with NASA on how to lead engineering activities, and a year-long high school freshman technical education course.

Over the past five years, Design Squad has built a community committed to fostering a positive image of engineering. Through partnerships with more than 100 engineering and education organizations, we have worked together to deliver engaging engineering activities to places where 9- to 13-year-olds can be found: afterschool programs, schools, museums, and malls. Activities, which our partners often fund through sources in their own local communities, include training other educators and engineers, hosting public events, organizing camps and afterschool programs, linking to our website, highlighting Design Squad on their email lists, and distributing our educational resources. Their extensive activities result from the fact that not a lot of other resources both fill the need for engineering education *and* are turn-key and accessible.

For More Information

Contact Marisa Wolsky, Executive Producer, at marisa_wolsky@wgbh.org or visit the project's website at http://pbskids.org/designsquad.

Executive Summaries of the aforementioned evaluations can be found on http://informalscience.org.

Engineering High School Biology into the 21st Century

Background

The *Next Generation Science Standards* integrate engineering practices as a core method for learning science and as a 21st century skill set that all students must develop. Engineering is transforming our world, serving as the core of the innovation economy and touching all aspects of our lives. But the gap between where we need to go and classroom reality is particularly salient in high school biology, where memorization is king and engineering practices and outcomes are largely absent, even though biotechnology is exploding. As biology is typically a first exposure to high school-level science, it is particularly unfortunate that students experience such an uninteresting, low-tech, memorization-driven approach.

We present a new approach to teaching core biology concepts (inheritance and evolution), involving engaging engineering design challenges (breeding rare animals for a zoo or breeding rare insects to help children in developing nations) that students solve using a combination of inexpensive hands-on materials that integrate modern biotechnologies and simple computational simulations.

These materials are made available to teachers through an online tool called iPlan, that gives just-in-time guidance on the how and why of the curriculum steps, an opportunity for teachers to customize the materials to their own classroom needs, an opportunity to see how other teachers have customized each lesson, and an opportunity to engage in discussions with other teachers about these materials.

Documented Results

Through the engineering design challenges, students see purposes and applications of science not normally presented in a science classroom. Our research finds that high school students taught through engineering challenges see a doubling in interest in engineering careers, and the effect is driven by coming to see that engineering helps to solve the world's problems. Because students are asked to reason through how to apply biology concepts and computational tools to solve the problem, they build deeper understandings of inheritance and evolution concepts. Our research on engineering design-based learning has found improvements in science learning for all students, with the largest gains shown by students traditionally underrepresented in science.

Through use of these materials, teachers also develop a deeper understanding of the concepts they are teaching as well as learn about engineering design practices, which many teachers have little prior training.

Potential Applications

Variations of the materials have been used successfully across multiple states in a range of urban, suburban, and rural school districts in the following high school science courses: Biology 1, Honors Biology, Ecology, and AP Biology.

For More Information

Send email to schunn@pitt.edu or visit http://www.lrdc.pitt.edu/schunn/research/design.html.

Engineer Your World: Engineering Design and Problem Solving for High Schools

Background

Engineering design is not simply a useful tool for teaching science and mathematics content, but it is also a unique discipline in which science and mathematics are employed as tools for solving design challenges. With generous support from the National Science Foundation (NSF) and in partnership with national organizations including NASA, the UTeachEngineering program at the University of Texas, Austin, has undertaken to demonstrate how rigorous engineering content can be deployed in secondary classrooms. Together, we have developed, piloted, refined, and deployed a year-long high school engineering course built on a foundation of solid research in the learning sciences, couched in the context of a rigorous engineering design process, and scaffolded to build engineering skills and habits of mind. We have also tested a variety of teacher preparation and support models that continue to evolve in response to the needs of our diverse teacher population.

Engineer Your World actively engages students in authentic engineering practices to build engineering skills and habits of mind. The course scaffolds student learning over six units, each of which is structured as an engineering design challenge. The *Engineer Your World* classroom is a project-based environment in which approximately 80 percent of students' time is spent on hands-on activities, and the balance is spent on documenting and reflecting on their work, preparing presentations and reports, and participating in direct instruction. Students in the course employ a standardized engineering design process to address design challenges that can only be completed through the purposeful application of engineering principles and relevant mathematics and science concepts. These concepts, which may include both prior knowledge and new knowledge, are employed when and only when they are necessary for students' successful completion of the challenge at hand.

Prior to teaching *Engineer Your World*, teachers attend a targeted two-week professional development workshop designed to enhance both their engineering content knowledge and their pedagogical content knowledge. The workshop, the content of which is aligned to the course and its underlying learning standards, is appropriate for teachers from diverse backgrounds. It emphasizes active engagement and problem solving, conveys clear ideas about effective teaching and learning, and offers participants frequent opportunities for critical reflection on teaching.

Ongoing support for *Engineer Your World* teachers continues to evolve. Over the past three years, we have experimented with a variety of options including direct help from program staff to teachers, virtual resources, and engineer mentors from the public and private sectors. Based on observations by project personnel as well as feedback from teachers, administrators, mentors, and evaluators, UTeachEngineering has developed an integrative instructional coaching model that will be piloted with all *Engineer Your World* teachers in 2013–14. It is anticipated that a suite of supporting resources will eventually be connected to one another and to the course content through a hybrid of a learning management system and an online collaboration tool that is anticipated to launch in 2014–15.

Documented Results

In 2011–12, *Engineer Your World* was piloted by 8 teachers with more than 230 students in seven Texas high schools. In 2012–13, the program expanded to 24 teachers serving 850 students in eight states. The *Engineer Your World* network includes urban, suburban, and rural schools with student populations ranging from a few hundred to approximately 3,000. The program is offered in STEM academies and comprehensive high schools, in single-gender and mixed-gender classrooms, and at all grade levels from 9 through 12. *Engineer Your World* teachers are similarly diverse, with experience ranging from 0 to 24 years of teaching. Some have engineering degrees or engineering work experience, while others have had no engineering exposure prior to teaching the course.

All *Engineer Your World* teachers participate in research and evaluation activities. Over the past two years, the project has examined student artifacts and pre-/post-tests, gathered informal feedback during classroom visits, and engaged an external evaluator to conduct a comprehensive evaluation of the curriculum and teacher support programs. While these efforts are ongoing, they have already led directly to such revisions as modification of course scaffolding, streamlining of course materials, development and testing of various student assessment instruments, creation of an instructional coaching model, and conception of an online learning management system/collaboration tool.

Potential Applications

Engineer Your World aligns with the *Next Generation Science Standards* as well as a number of states' standards for engineering science credit. While the course was originally developed to meet the requirements of a junior-/senior-level science course in Texas, it is being offered successfully to freshmen and sophomores in a variety of school settings across the nation. The success of the course at this level has afforded opportunities for collaboration with schools seeking to introduce engineering early in the high school course sequence. A number of partnerships between UTeachEngineering and other national organizations are emerging around this model.

For More Information

Berland, L., Allen, D., Crawford, R., Farmer, C., & Guerra, L. (2012). Learning sciences guided high school engineering curriculum development. American Society for Engineering Education. (Accepted for publication in annual conference proceedings.)

Farmer, C., Allen, D., Berland, L., Crawford, R., & Guerra, L. (2012). Engineer Your World: An innovative approach to developing a high school engineering design course. American Society for Engineering Education. (Accepted for publication in annual conference proceedings.)

Guerra, L., Allen, D., Berland, L., Crawford, R., & Farmer, C. (2012). A unique approach to characterizing the engineering design process. American Society for Engineering Education. (Accepted for publication in annual conference proceedings.)

Visit www.engineeryourworld.org and [www.uteachengineering.org.](http://www.uteachengineering.org)

Integrating Engineering and Literacy (IEL)

Background

There is a growing demand for engineering education in the pre-college classroom, particularly in ways that work with other aspects of curricula. Integrating Engineering and Literacy (IEL) projects use children's texts as contexts for students' initiation and early progress in practices of engineering. In particular, we focus on students' (1) recognizing and scoping problems, with attention to the "client's" situation, (2) conceptualizing and planning possible solutions, and (3) fabricating, testing, and revising their ideas. Time limitations generally do not permit students to dive deeply into all three respects, but we intend that any particular experience involves the first and second or the second and third, with opportunities for all three over the year. What is important throughout is that students get to come up with their own ideas, and one indication of success is the diversity of ideas the class considers—such as regarding clients' needs, ideas for solutions, or possibilities for improving on prototypes.

We are studying how students understand and how teachers facilitate activities of identifying and defining problems to solve, conceptualizing possible solutions, and building and testing prototypes. We are in our third year of five, having worked in 19 classrooms across four schools.

Documented Results

In the broadest terms, data from these integrated engineering and literacy projects show that students are capable of identifying and scoping problems, of considering the client in their design, and of acting on these plans to create working prototypes that they then present to their classmates. That is, we find children have ample intellectual resources for engaging in these activities as nascent engineers. We have also seen evidence of synergy with literacy; during their engineering experiences, students formed insights into the characters and turned back to the text to envision the characters' situations.

The data also suggest differences among texts in providing contexts for student engineering. The most difficult are anthologies, which provide only a few pages from any particular story. With little development of plot and characters, we have not seen the depth of consideration about nature of the engineering problems and the characters as clients that we have in full-length books. Fantasy books also pose a challenge in that it is easy to have "magic" solve problems, and we find students walking a fine line of the real and the fantastical worlds. For example, some students have read *The Mouse and the Motorcycle* by Beverly Cleary: A mouse drives a motorcycle into a trashcan and now must escape using what is available in the trash. Interesting questions and discussion arise around what to suppose a motorcycle-riding mouse can do, and some solutions have involved fantasy to the point of being impossible to test.

In contrast, *The Mixed-up Files of Mrs. Basil E. Frankweiler*, by E. L. Konigsburg, is about two children whose problems center on the challenge of living undetected in the Metropolitan Museum of Art in New York City. It does not involve fantasy (over the natural world), and it has been fairly consistent in producing good results, such as students arguing about what materials the two protagonists would have had access to along with how they would most likely use their limited funds (a feature of the story) to buy materials. We have also seen students return to the text to check details, as they scope the problem and assess the viability of their solutions. *Shiloh*, by Phyllis R. Naylor has shown similar results through a "real" natural world with sympathetic protagonists.

Finally, our data suggest the importance of teacher perceptions and decisions. Teachers who have a preconceived notion of what solutions are "the right ones" may redirect student ideas, and in some cases reduce student enthusiasm as the project goes from students' building their own ideas to building the teacher's idea. More effective practices involve teachers' willingness to let students have and pursue their own ideas, recognizing those ideas and responding substantively and constructively.

Potential Applications

IEL projects can be taken up in any class that reads books! We plan to leverage the *Next Generation Science Standards* (NGSS) to promote these approaches and to work with our long-time partner, LEGO Education.

For More Information

Visit http://ceeo.tufts.edu.

Society's Grand Challenges for Engineering as a Context for Middle School STEM Instruction

Background

The inclusion of engineering into the *Next Generation Science Standards* leaves both science education and engineering educators with cause for both excitement and alarm. Science education watchers, for example, fear loss of science instruction time and obfuscation of the nature of science, while teachers may assume that "build a bridge Fridays" will provide sufficient science instruction for an entire week. Engineering counterparts fear that a focus on student competition to build structures will pass as engineering while presenting students with a narrow view of engineering careers and omitting key engineering principles. Alternatively, integration of engineering with math and science instruction may be viewed as an educational opportunity—a means to engage students through compelling real-world societal challenges, and to leverage the natural linkages between science and engineering to facilitate learning *both* subjects.

Society's Grand Challenges for Engineering as a Context for Middle School STEM Instruction is a research project initiated at University of Wisconsin-Madison, in 2010 with support from the NSF ITEST program, with the objective of exploring the integration of socially motivated engineering into math and science classrooms. An interdisciplinary team of engineers and science educators have developed a set of model modules based on the National Academy of Engineering's (NAE) Grand Challenges for Engineering Initiative, to serve as a model for the integration of engineering into science and math curricula in a way that accurately portrays both the distinct features of the disciplines and their interdependence.

Our emphasis on altruistic engineering projects is motivated by the NAE's Extraordinary Women Engineers Project, which has identified messaging as an important factor in the low representation of women in undergraduate engineering programs. An extensive survey of high school students systematically concludes that messaging about engineering that emphasizes "math and science" and the notion of a "challenge" is not aligned with key motivators for girls. Rather, they find that messages that focus on features of the engineering profession not widely emphasized, such as "making a difference in the world" and "creativity," hold much stronger appeal. The survey also found that both male and female students rank engineering as the least desirable among professions listed, behind teacher, doctor, lawyer and business, and that only 29% of girls (compared with 51% of boys) say engineering would be a good or very good profession for someone like them.

Middle school students were selected as the target population because middle school is a critical juncture during which many students begin to seriously consider career options. Attitudes about self and the world of work that are held during this period form the foundational belief system from which students draw to set career goals for themselves and to choose high school courses and activities. This is also a period during which comprehensive approaches to career awareness and exploration can be particularly impactful and have been shown to increase students' awareness of and self-efficacy for a broad range of career options including STEM careers.

Six curriculum units based on four Grand Challenge themes have been developed and are currently being piloted at six Wisconsin public middle schools:

- Health Care: Biomedical Imaging
- Water Resources: Drinking Water Quality
- Improving Aging Infrastructure:
  - Bridge Restoration
  - Seismic Retrofitting
- Solar Energy:
  - Solar Cooking
  - Photovoltaics for Lighting

Each unit includes detailed guides for both teachers and students, and employs realistic fictional scenarios to engage a broad spectrum of students through role play as engineers as they tackle specific design problems inspired by real societal needs. Standards-based middle school science, math, and engineering content are embedded within the modules, consistent with recommendations in the *Next Generation Science Standards*.

The research component of this project has been led by team members with expertise in education, including a particular focus on self-efficacy for STEM. Data collection is underway using validated instruments to assess student outcomes, with an emphasis on gender, race/ethnicity, and socio-economic status. Research questions address whether participating students (compared with a control group) (1) report higher levels of STEM career interests, (2) report higher math and science self-efficacy and outcomes expectations, and (3) engage in more exploration of STEM careers.

Potential Applications

The Grand Challenges curriculum units have been designed for integration into core math and science classrooms at the middle school level. The Grand Challenges modules offer a strategy for meeting the new engineering standards, and serve as a model for integration of engineering into math and science curricula.

For More Information

Contact Amy Wendt, wendt@engr.wisc.edu.

Engineering is Elementary Engineering and Technology Lessons for Children Problem Solving, Inquiry, and Innovation

Background

The Engineering is Elementary (EiE) project fosters engineering and technological literacy among elementary school students and educators. EiE has created a research-based, standards-driven, and classroom-tested curriculum that integrates engineering and technology concepts and skills with elementary science topics. EiE lessons not only promote science, technology, engineering, and mathematics (STEM) learning in grades 1–5, but also connect with literacy and social studies. To date, EiE has reached over 2.7 million students and 32,000 teachers and is presently used in all 50 states.

EiE Project Goals

(1) Increase children's technological literacy. (2) Improve elementary educators' ability to teach engineering and technology. (3) Increase the number of schools in the U.S. that include engineering at the elementary level. (4) Conduct research and assessment to further the first three goals and contribute knowledge about engineering teaching and learning at the elementary level.

The EiE Curriculum

Each EiE unit integrates an elementary school science topic with a specific field of engineering. EiE units are designed to engage students in the engineering design process and include the following:

- **Storybooks** featuring child characters from a variety of cultures who introduce students to an engineering problem. Students are then challenged to solve a similar problem. In addition to providing context, the storybook also serves to introduce engineering and technology concepts and terms, and reinforce science vocabulary.
- **Lesson plans** for teachers. EiE teacher guides include vocabulary, learning objectives, tie-in science content, detailed materials and preparation sections, and step-by-step instructions on how to facilitate each EiE activity.
- **Duplication masters (DMs)** for student handouts. To accommodate differences in students' abilities, EiE units contain two versions of many DMs: Basic (lower reading level, less cognitively complex, suggested for grades 1 and 2) and Advanced (higher reading level, more cognitively complex, suggested for grades 3–5).
- **Student assessments and rubrics**. Multiple-choice and open-ended questions that teachers can use to gauge their students' understanding and learning of engineering, technology, and science concepts are provided in each EiE unit. Rubrics are provided at the end of each lesson to help teachers evaluate students' progress.
- **Background information** and additional reference resources for teachers.

Each EiE unit takes about 8–10 hours of instructional time to complete. EiE has developed materials for 20 elementary science school topics and engineering fields. All EiE units are designed to meet the ITEEA Standards for Technological Literacy. At its core, EiE is designed to have students engineer. The program develops interesting problems and contexts and invites children to have fun as they use their knowledge of science and engineering to design, create, and improve solutions.

Professional Development
Engineering is a new discipline for many teachers. To learn more about engineering and technology content and pedagogy, the EiE project offers workshops for elementary school teachers and teacher educators. These sessions provide teachers with an overview of engineering and technology concepts and skills, review the structure and philosophy of the EiE curriculum, engage participants in activities from the curriculum, and foster reflection about effective instructional strategies. EiE workshops are held at the Museum of Science, and EiE staff are also available to facilitate off-site workshops as requested.

Research and Assessment
Research, evaluation, and assessment studies are integral to the development of the EiE curriculum, and an important facet of our curriculum development philosophy. The EiE team believes that a high-quality curriculum is one that is well-researched and thoroughly tested at all stages, from garnering a basic understanding of what students and teachers know about engineering and technology to the published product. From its inception in 2003, EiE has been committed to creating high-quality teacher guides and professional development for teachers and a world-class curriculum for students through multiple cycles of research, development, testing, and improvement. We are collecting qualitative and quantitative data from students and teachers across the nation to better understand how children best learn about engineering and how our materials impact their understandings.

National statistical and controlled studies indicate that children who engage with EiE materials have a much better understanding of engineering and technology than children who do not use EiE. Findings have also shown that children who engage with EiE perform better on assessment questions about the related science topic than children who do not use EiE.

Multimedia Initiatives
The EiE website contains multimedia resources, such as a 16-minute informational video that provides an overview of the EiE project, footage of students engaged in EiE activities, and teacher interviews. The website also has a series of shorter videos designed to help educators organize and prepare materials for EiE lessons, as well as longer videos which capture footage of classroom teachers using EiE with their students. These longer videos include teacher interviews in which teachers reflect on their engineering practice and pedagogy. In addition to video resources, the website has a Content Connections page that contains a searchable, dynamic database of lessons.

Out of School Time: Engineering Adventures
Engineering Adventures (EA) is a fun, engaging, hands-on, engineering curriculum being created by the EiE team for use in out-of-school-time settings such as after-school and camp programs. EA challenges children to solve design challenges using creativity, teamwork, science, and engineering. EA is arranged as a series of thematic units, each focusing on a field of engineering. EA is not yet available to the public.

For more information
Visit the EiE website: http://www.mos.org/eie.

CAPSULE: How to Use Engineering-Based Learning (EBL) in High School

Background
With systematic structure, organized tools, proper resources, and hands-on real-world experiences, engineering-based learning (EBL) can be an effective teaching and learning model for high school STEM courses. EBL combines well-known tools from science and engineering to create a pedagogical process to enhance student-centered learning across multiple STEM disciplines. Unlike project-based learning (PBL), EBL is a systematic method for students and teachers to find an appropriate solution to a given open-ended real-world problem. EBL bridges the gap between STEM abstract concepts and real-life applications. Thus, EBL has the potential to motivate students to pursue college STEM degrees and join the STEM workforce.

The CAPSULE curriculum and EBL methodology is aligned with the following standards documents: *National Educational Technology Standards* (issued by ISTE), the *Standards for Technological Literacy* (issued by ITEA), the *Next Generations Science Standards*, and the *Massachusetts State Framework*, to allow for seamless scale-up at the national level.

There are a variety of ways to implement EBL in the classroom: with small, multiple capstone projects or one culminating experience; by unit, semester, or year. Each teacher can create a unique implementation plan to meet the conceptual needs of their students and fit into their curriculum plan.

A unit-based implementation lasts from one to three weeks. Teachers will develop a capstone experience particular to the STEM unit they are teaching. For some teachers, this type of implementation is easier because it has a narrower focus than a semester- or year-long capstone experience. This type of implementation allows students to experience small-scale, directed-learning environments. In addition to the hands-on component, students understand and reinforce specific theoretical principles while experiencing the capstone challenge.

The longer projects provide students with a real-world experience where they have to perform and finish the project in stages over time versus a day- or week-long project. Both the semester- and year-long capstone experiences provide students with an opportunity to design their own solutions to provided problems. In some cases, teachers allow students to choose their own problems to solve. Many teachers have tied in their current units to a part of a capstone experience.

Teacher Professional Development
CAPSULE includes a two-week/80-hour professional development program for high school teachers, with a three-graduate-credit option. The program focuses on the engineering-based learning methodology and its implementation in the classroom with the goal of attracting more high school students into STEM college careers. Week one of CAPSULE focuses on learning the concepts and tools involved in engineering-based learning, and culminates with participants developing and presenting a mini-capstone poster and presentation. Participants are presented with an open-ended problem such as “design a new office bookcase.” They are given a set of constraints and requirements, and divided into groups to solve this problem. The first week is meant for teachers to live the EBL experience in its entirety. Week two focuses on helping

teachers apply the new tools, theories, and techniques they learned in the first week to their classroom teaching. Teachers are able to discuss with colleagues and the CAPSULE team how to best integrate EBL into their classroom.

The project has trained 82 high school STEM teachers (grades 9–12) from 45 school districts, and 62 distinct high schools. More than 4,500 students have participated in the program over the three years.

Potential Applications

A geometry teacher who works in an urban, lower income school with a high Asian and African American population successfully integrated multiple EBL lesson plans in her classroom. She helped her freshman students to connect math concepts such as probability, permutations, and pre-calculus through EBL projects such as the "Fist of Doom." "Fist of Doom" is a design challenge wherein students have to research, design, and develop a structure that will protect a Pringle™ potato chip from damage caused by a textbook being dropped five feet above the chip. She also asked her junior pre-calculus students to redesign their current home into an "ideal" home based on certain constraints such as the number of rooms, types of rooms, and current house carbon footprint. This teacher reported that her students discovered how the math they were learning in the classroom was applicable to their life and potential careers.

Another teacher provided students with free, downloadable software, called stop-animation motion (SAM) videos, for their geometry capstone project. SAM videos allow students to design and create flipbook-like movies. By utilizing this software, students are able to take a challenging problem or theory and creatively construct a story and application to assist in learning and remembering that concept. One particular student struggled with understanding the applicability of the Pythagorean theorem. When he finished his video, he understood its importance in the design of not only his fictional bridge but also the bridge that he crosses every day to school.

For More Information

For more information, visit http://capsulenu.weebly.com/.

Elementary Engineering Teacher Professional Development: Initiation to Integration

Background

The Institute for P–12 Engineering Research and Learning (INSPIRE) at Purdue University carries out basic research, applied research, and evaluation on teacher professional development and student learning with engineering in formal and informal settings. Through a National Science Foundation Discovery Research K–12 (DR K–12) project, we have sought to investigate the impact of elementary engineering teacher professional development (TPD) on teachers' and students' knowledge, attitudes, and behaviors with regards to engineering. Our TPD has been delivered in the form of a one-week-long summer academy (~30 hours), a year of supported classroom implementation, a second three-day summer academy, and a second year of classroom implementation. The learning objectives for the academies are such that teachers will be able to:

- convey a broad perspective of the nature and practice of engineering,
- develop a level of comfort in discussing what engineers do and how engineers solve problems with elementary students,
- articulate the differences and similarities between engineering and science thinking, and
- use problem-solving processes (i.e., science inquiry, model development, and design processes) to engage their students in complex open-ended problem solving.

This work has resulted in the identification of three stages of teacher development that are evident as teachers launch into elementary engineering. In the first stage, there is always some level of fear of engineering that needs to be overcome in order to even "see" engineering as a fit for the elementary classroom. In the second stage, teachers need to work within their school systems to get through the first implementation of one or more engineering activities. At the third stage, teachers are ready to think about what makes these activities "engineering" and how these engineering activities integrate with the rest of the grade-level curriculum. This project has resulted in the TPD materials and practices as well as teacher and student assessments that are available through INSPIRE.

Documented Results

INSPIRE's research team is using the data collected through the DR K–12 project to investigate a number of questions around the impact of elementary engineering TPD and classroom implementation of engineering. The student data consists of pre-post academic year assessments (i.e., Draw-an-Engineer Test (DAET), Science and Engineering Knowledge Test (SKT), and Engineering Identity Scale (EIDS)) and student interviews, including the prompts for the Design Process Knowledge Task (DPKT). The teacher data has been collected through various instruments that assess teacher knowledge of engineering, teacher beliefs about science, technology, engineering, and math (STEM) and STEM education, and teacher practices with engineering education. A large part of the research effort has focused on instrument development and assessment strategies. We are in the midst of significant data analysis.

A sampling of findings can be found at:

Carr, R. L., Diefes-Dux, H., & Horstman, B. (2012). Change in elementary student conceptions of engineering following an intervention as seen from the Draw-an-Engineer Test. *Proceedings of the 119th ASEE Annual Conference and Exposition*, San Antonio, Texas.

Douglas, A., & Diefes-Dux, H. A. (2013). Elementary teachers' two-year implementation of engineering: A case of success. *Proceedings of the 120th ASEE Annual Conference and Exposition*, Atlanta, GA.

Dyehouse, M, Diefes-Dux, H. A. & Capobianco, B. (2011). Measuring the effects of integrating engineering into the elementary school curriculum on students' science and engineering design content knowledge. *Proceedings of the 118th ASEE Annual Conference and Exposition*, Vancouver, British Columbia, Canada.

Hong, T., Purzer, S., & Monica C. (2011). A psychometric re-evaluation of the Design, Engineering and Technology (DET) survey. *Journal of Engineering Education*, *100*(4), 800-818.

Hsu, M.-C., Cardella, M. E., & Purzer, S. (2012). Elementary students' engineering design process knowledge: Instrument development and pilot test. *Proceedings of the 119th ASEE Annual Conference and Exposition,* San Antonio, TX.

Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H. A. (2011). The development of a systematic coding system for elementary students' drawings of engineers. *Journal of Pre-College Engineering Education Research (J-PEER)*, 1, 1, 49-62.

Yoon, S. Y., Kong, Y., Diefes-Dux, H. A., & Strobel, J. (2013). Elementary teachers' evaluations of professional development in engineering. *Proceedings of the 120th ASEE Annual Conference and Exposition,* Atlanta, GA.

Potential Applications

Our elementary engineering TPD model, with minimal consultation, could be adapted to other educational contexts. In the formal setting, it has been implemented with as many as 65 teachers in one session. The TPD has been delivered to teachers whose student populations are diverse in terms of socio-economic status, ethnicity, and academic preparation. Beyond formal settings, the TPD model may be suitable, with some modification, for individuals working with engineering in informal settings.

For More Information

Visit the INSPIRE website: http://www.inspire-purdue.org/.

Engaging Youth through Engineering (EYE) Modules: Integrating and Bringing Relevance to Core Middle Grades Mathematics and Science Content

Background

Engaging Youth through Engineering *(*EYE) is a partnership-driven K–12 economic development initiative underway in Mobile, Ala., that is spearheaded by a local nonprofit education entity in collaboration with a large urban school system, higher education, and area business and industry. Its purpose is to produce high school graduates eager and able to meet the growing demand for tech-savvy workers who are also innovative problem solvers. EYE uses engineering design challenges to bring practical relevance and rigor to K–12 math and science curricula. At the middle-grades level, local and National Science Foundation funding are enabling EYE to develop a set of integrated STEM instructional units, the EYE modules, to inspire and motivate all middle-grades students, especially those typically underrepresented in STEM, to take the high school courses needed in preparation for 21st century workforce needs. Each EYE Module is designed such that students use engineering practices and apply required mathematics and science content to develop solutions to relevant problems facing humans today, fostering the development of engineering "habits of mind."

The set of eight EYE modules are comprehensive and extensive instructional guides for middle-grades teachers to implement collaboratively in mathematics and science classes. The modules address standards-based STEM content and practices that fill gaps between state-mandated and tested content and what business and industry say they need, including innovative problem solving, communication, and teamwork skills. Module-specific professional development and implementation materials kits accompany each module. The modules are not a complete engineering, technology, or STEM curriculum; rather, they supplement and support the existing mathematics and science curriculum. They are a set of comprehensive and extensive instructional guides that use design challenges and the engineering design process to engage middle-grades students in pursuing STEM careers and academics. The set of eight modules with their grade-level "Launcher" lessons involve about 50 hours of STEM exposure for each student during the three middle-grades years (6, 7, 8). Each EYE module requires from 6 to 10 lessons implemented in a combination of math and science classes. While the modules are designed to be used as a set, they may be implemented as independent units as well.

Documented Results

A longitudinal comparison study of the impact of the EYE modules on students was begun in 2011 and is following the cohort of sixth-grade students as they experience the finalized set of eight modules. This study will be completed in 2014. Other studies involving cohorts of students who experienced early drafts of the modules in grades 6–8 are producing encouraging indications of their impact on students, teachers, and the district. Initial results show the draft modules positively impacting students' interest in STEM careers and STEM capacity. These data also indicate that EYE students know more about engineering, are more interested in work resembling that found in STEM careers, are more receptive to science labs and other hands-on activities, and are more likely to have had a teacher or counselor talk about STEM fields than those in a matched comparison school. Standardized test data are showing a positive impact on module-specific science and mathematics content and that EYE may also be having an even greater impact on groups underrepresented in STEM, such as African-American students.

Qualitative data from multiple sources indicate a new and beneficial collaboration between the mathematics and science teachers following multiple years of using the modules. In addition, teachers report they now see strengths in many of their students that previously had gone unrecognized, specifically students receiving special education services. Often the special education students become the team leaders, gaining newfound respect from their classmates.

One compelling summative finding has already emerged from the study: the modules have served as a catalyst for a large urban school system (60,000 students, 17 middle schools, over 70% below poverty level) to initiate STEM reform. According to the superintendent, as a direct result of the EYE modules, the school system has developed and implemented revised mathematics and science standards that incorporate engineering. And, to ensure sustainability of these reform efforts, the school system has established a new district-level position, STEM resource teacher, and filled the position with one of the teachers involved in the EYE module development and field tests.

Potential Applications

As the nation is calling for K–12 schools to better prepare students to meet industry's need for STEM-literate workers and innovative problem solvers, there is an unprecedented demand for quality-integrated STEM curricula that include engineering and supports both mathematics and science content to produce these students. The EYE modules are showing their potential to engage students around STEM careers, producing students with engineering habits of mind, and, as importantly, serving as a catalyst for districts to include integration of science, technology, engineering, and mathematics into their core curriculum.

Besides using the EYE modules to bring integrated STEM to core middle-grades mathematics and science classes, other applications of the modules are emerging. One involves using the EYE modules as part of a STEM professional development offering for districts in the Boston region that are interested in integrated STEM at the middle grades. Districts send grade-level pairs of middle-grades teachers to learn about integrated STEM through study and implementation of the EYE modules. Graduate-level course credit is provided for participants who complete the week-long summer workshop, implement the modules, and complete follow-up activities, including gathering implementation data.

Another interesting application of the modules is their use in building leadership capacity for STEM sustainability in the Mobile area. Multiple tiers of leaders are being developed—including business/industry leaders, school district administrators, instructional specialists, informal and formal educators of teachers, and classroom teachers. The EYE modules are used as a tool to deepen understanding of the "what, why, and how" of STEM, enabling these potential STEM leaders to better advocate for and support STEM education for all students.

For More Information

Visit www.maef.net or contact Susan Pruet at spruet@maef.net.

Implementing K–12 Engineering Standards through STEM Integration

Background

STEM (science, technology, engineering, and mathematics) integration at the K–12 level is gaining national and international attention. Many U.S. national documents have laid the foundation for the connections between the disciplines. Engineering can be considered the integrator in STEM integration. However, a clear definition or tradition of what constitutes a quality engineering education at the K–12 level has not been established. At the college level, the Accreditation Board for Engineering and Technology (ABET) has guided the development of engineering programs through its accreditation process, but there is no similar process at the K–12 level. As a result, we are left with a number of questions about the best methods by which to effectively teach engineering at the K–12 level and how that plays into the integration of the other STEM disciplines.

The purpose of the current research has been the development of a framework for describing and evaluating engineering at the K–12 level in order to help further our understanding and development of robust engineering and STEM education standards and initiatives. *A Framework for Quality K–12 Engineering Education* is the result of a larger research project focused on understanding how engineering and engineering design are implemented in K–12 classrooms at the classroom, school, district and state levels. The framework is designed as a tool for evaluating the degree to which academic standards, curricula, and teaching practices address the important components of a quality K–12 engineering education.

Development of the K–12 Framework for Engineering

The framework's key indicators for a quality K–12 engineering education were determined based on an extensive review of the literature, established criterion for undergraduate and professional organizations, and in consultation with experts in the fields of engineering and engineering education. The order of the key indicators within the framework was carefully chosen based on the degree to which the benchmark is unique or central to engineering as compared to other disciplines. Key indicators that appear near the beginning (e.g., Processes of Design) are thought to be defining characteristics of engineering. Whereas, key indicators that appear later (e.g., Communication), although essential for engineering education, are concepts that are required for success in multiple disciplines.

An abbreviated form of *A Framework for Quality K–12 Engineering Education* is below:

- **Process of Design (Comp-POD):** Design processes are at the center of engineering practice. Solving engineering problems is an iterative process involving preparing, planning, and evaluating the solution. Students should understand design by participating in:
  - **Problem & Background (POD-PB):** Identification or formulation of engineering problems, and research and learning activities necessary to gain background knowledge.
  - **Plan & Implement (POD-PI):** Brainstorming, developing multiple solutions, and judging the relative importance of constraints and the creation of a prototype, model, or other product.
  - **Test & Evaluate (POD –TE):** Generating testable hypotheses and designing experiments to gather data that should be used to evaluate the prototype or solution, and to use this feedback in redesign.

- **Apply Science, Engineering, and Math Knowledge (SEM):** The practice of engineering requires the application of science, mathematics, and engineering knowledge, and engineering education at the K–12 level should emphasize this interdisciplinary nature.
- **Engineering Thinking (EThink):** Students should be independent and reflective thinkers capable of seeking out new knowledge and learning from failure when problems within engineering contexts arise.
- **Conceptions of Engineers & Engineering (CEE):** K–12 students not only need to participate in an engineering process, but they must also understand what an engineer does.
- **Engineering Tools & Processes (ETool):** Students studying engineering need to become familiar and proficient in the processes, techniques, skills, and tools engineers use in their work.
- **Issues, Solutions & Impacts (ISI):** To solve complex and multidisciplinary problems, students need to be able to understand the impact of their solutions on current issues and vice versa.
- **Ethics (Ethics):** Students should consider ethical situations inherent in the practice of engineering.
- **Teamwork (Team):** In K–12 engineering education, it is important to develop students' abilities to participate as a contributing team member.
- **Engineering Communication (Comm-Engr):** Communication is the ability of a student to effectively take in information and to relay understandings to others in an engineering context.

Potential Applications

The framework has uses as an evaluation and development tool for policy and research regarding K–12 engineering and STEM education. Additionally, the framework can be useful for curriculum development both for the development of units of instruction and for the development of scope and sequencing throughout the K–12 curriculum. As part of this work, a set of curriculum materials called *PictureSTEM* are in various stages of development for grades K–5. These materials use the framework to guide their development. There is also the potential for using this framework as a guide for school-level engineering education reform.

For More Information

Moore, T. J., Tank, K. M., Glancy, A. W., Kersten, J. A., & Ntow, F. D. (2013). *The status of engineering in the current K–12 state science standards (Research to Practice)*. Scientific paper to be presented at the 2013 American Society of Engineering Education, Atlanta, GA.

Tank, K. M., Moore, T. J., Pettis, C., & Fehr, A. (in press). Designing animal habitats with kindergartners: Hamsters, picture books, and engineering design. *Science and Children.*

PictureSTEM curricula can be found at https://sites.google.com/a/umn.edu/picturestem/. Contact Tamara Moore at tamara@umn.edu with questions regarding the overall work from the CAREER STEM Integration project.

Science Learning through Engineering Design (SLED)

Background

The engineering design approach for teaching science concepts has led to middle school student knowledge gains in core science concepts when compared with a scripted inquiry approach. By blending math and science disciplines, engineering design provides a strong mechanism to facilitate integrated instruction and connections among concepts and to the real world, building student understanding and appreciation for both content areas. While empirical research validates the use of engineering design at the secondary level, such efforts are almost nonexistent in the elementary classroom, particularly in rural schools that often lack any type of curriculum integration. The Science Learning through Engineering Design (SLED) vision is to increase grade 3–6 student learning of science by developing Indiana's first integrated, engineering design-based approach to elementary/intermediate school science education. Engineering, science, technology, and education faculty for Purdue University work directly with 90 elementary/intermediate inservice teachers, 70 preservice elementary teachers, and 2,500 students in the four partnering Indiana school districts: Taylor Community School Corporation, Plymouth School Corporation, Lafayette School Corporation, and Tippecanoe School Corporation.

Project goals are to (1) create a partnership of university engineers and scientists, teacher educators, school teachers and administrators, and community partners to improve science education in grades 3–6 through the integration of engineering design; (2) enhance the quality, quantity, and diversity of inservice and preservice teachers prepared to utilize engineering design to teach science through authentic, inquiry-based, multi-disciplinary design projects; (3) adapt, refine, and test existing project- and design-based curriculum materials/tasks, and where necessary, develop new ones to support the teaching of elementary science through authentic, inquiry-based, multi-disciplinary design projects; and (4) generate evidence-based outcomes for understanding how teachers teach science through engineering design and how young students learn science concepts through design-based activities.

The partnership uses summer institutes, linkages with Purdue preservice teachers, cyberinfrastructure, action research, and graduate coursework to equip teachers with design-based pedagogical skills and science content.

Potential Application

SLED addresses a newly introduced Indiana Academic Science Standards core standard entitled "the design process," which requires Indiana K–12 teachers to have the knowledge, skills, and resources necessary to teach science through engineering design. SLED is creating an effective model for high-quality science teacher professional development in Indiana and a more systematic trajectory for merging design and inquiry curriculum in Indiana schools.

Sustainable impacts include:

- inservice and preservice professional development to teach science through authentic, inquiry-based, multi-disciplinary design projects;
- a cyber-enabled community of engineering design educators accessing a library of tested, design-based curriculum materials to support teaching science in grades 3–6;
- formal integration of engineering design-based curricula in grades 3–6 of partner schools; and
- tested resources for addressing unique challenges of supporting integrative engineering design curriculum in rural schools.

For More Information

Contact Brenda Capobianco: bcapo@purdue.edu.

Project MINDSET: An Engineering Modeling Approach to Teaching High School Mathematics

Background

Mathematics **IN**struction using **D**ecision **S**cience and **E**ngineering **T**ools (MINDSET), an NSF-funded project, is a collaboration between educators, engineers and mathematicians at three universities to achieve the following goals:

1. Enhancement of students' mathematical ability, especially their ability to formulate and solve multi-step problems and interpret results
2. Improvement in students' attitude toward mathematics
3. Adoption of the curriculum in two states

To achieve the project goals, MINDSET created four primary project objectives. They are:

Tools for Instruction of K–12 Students.

- Objective 1: Develop a new one-year high school curriculum and textbook using engineering-based decision-making tools and modeling to teach standard mathematics topics in a non-calculus-based fourth-year high school mathematics course.
- Objective 2: Through a multi-state, multi-school district assessment, show statistically significant improvement in students' mathematical ability, particularly in multi-step problem solving and interpretation of results, and in motivation and attitude toward mathematics.

Tools for Instruction of K–12 Teachers.

- Objective 3: Develop an infrastructure to effectively train and support teachers who will teach the curriculum.
- Objective 4: Demonstrate that this infrastructure is sustainable and sufficiently flexible such that it can be successfully reproduced and utilized by others.

MINDSET has achieved its goals and objectives. The project is now in its final year and, through a multi-state, multi-school district assessment, has shown a 14.5% statistically significant improvement in students' mathematical ability, and a small (2%) improvement in motivation and attitude toward mathematics. The Industrial Engineering and Operations Research techniques used in the course are mathematics-based decision-making methods routinely used to model large systems. These models are used in manufacturing, healthcare, banking, government agencies, insurance, and food industries, in theoretical and applied science, and in all engineering disciplines. They are non-calculus based and build on a foundation of algebra, probability, and statistics. The curriculum supports mathematical learning through the contexts (e.g., industry and government) that relate directly to students' lives. It increases problem-solving skills to enhance students' future success. Further, anecdotal evidence indicates that MINDSET appears to be of interest to students, and has a strong potential to engage and encourage high school students from underrepresented groups to pursue STEM careers.

Documented Results

The MINDSET curriculum requires two years of high school algebra for a prerequisite and uses interesting and innovative contexts that high school students can relate to—such as standing in line, scheduling part-time jobs, or designing a school bus route—or are modified from issues in industry. The new curriculum is exciting and challenging and engages students that are not in a calculus track, incorporating a broadly relevant curriculum that reinforces and enhances skills in basic mathematics, Algebra I and II, probability, data analysis, and statistics. The curriculum targets, but is not exclusive to, the lowest 50% of high school seniors, many of whom will go directly into the workforce, seek a two-year associate's degree, or attend college in non-STEM majors. It relies on computer tools with extensive use of engineering modeling and Excel©. The use of Excel© is at such a level that students may be prepared to take the National Microsoft Excel Basic Certification Exam, providing a valuable certification for those students entering the workforce directly from high school. Consequently, the MINDSET curriculum integrates engineering and technology into an advanced high school mathematics curriculum.

Potential Applications

The MINDSET curriculum targets those states that have or are implementing a fourth-year mathematics requirement to graduate high school. Specifically targeted are those students who will not take pre-calculus but need an advanced mathematics course with an Algebra II prerequisite. This is generally the lowest 50% of high school seniors in terms of mathematical ability. Most of these students will go directly into the workforce, seek a two-year associate's degree, or attend college in non-STEM majors. The curriculum's support infrastructure, teacher identification and training for workshops, supplemental materials development, low cost of the two-volume textbook, and its availability in both electronic and printed form all situate the MINDSET project to go to scale. Currently, a scale-up proposal is under evaluation.

For More Information

Contact Robert Young at young@ncsu.edu or Karen Keene at keene@ncsu.edu.
Visit http://www.mindsetproject.org/index.php/publications.

Biomimetic MicroElectronic Systems Engineering Research Center

Background

The NSF-sponsored Biomimetic MicroElectronic Systems Engineering Research Center (BMES ERC) at the University of Southern California (USC) has developed an extensive K–12 outreach program. The Center's various outreach initiatives have brought the excitement of scientific discovery to hundreds of elementary and secondary school students as well as to their teachers and extended family members. Leveraging the substantial resources and human capital of the BMES ERC, educational curricula that are experiential, hands-on, and aligned with California State Science Standards have been developed and implemented directly into K–12 classrooms. Lesson plans are rich in activities that demonstrate the scientific process, thus ensuring that students learn science by doing science. BMES research is used as a focal and reference point so that K–12 science is contextualized, helping to address the perennial question, "Why do I need to know this?"

Mentoring is a key component of the outreach initiative. It is interwoven throughout the program, and it facilitates the establishment of a culture of connectivity in which mentors pass acquired knowledge and skills onto successively younger generations of students and inculcates the idea of lifelong learning.

The BMES ERC Outreach is composed of a number of programs targeted at K–12 students, teachers, and parents.

1. *The Engineering for Health Academy (EHA)* increases awareness of and support for science and engineering among high school students. The EHA is designed as a small learning community with the goal of introducing students to the spectrum of biomedical engineering (BME) career opportunities. EHA students make a three-year commitment to the program beginning in grade 10 and transition through a series of four integrated core courses. Curriculum development is driven by current/ future anticipated needs of the BME field so that graduating EHA students will have advanced preparation for the demands of a rigorous post-secondary college program in biomedical engineering.
2. In their senior year, EHA students enroll in the *Research Experience Capstone Class* and are matched with USC research laboratories. This offers students the rare opportunity to gain firsthand experience conducting research in a university setting. Students are also able to use the factual information and technical skills they acquire in the EHA core courses and put them into practice. In partnership with USC graduate student mentors, EHA students develop and execute an appropriate year-long research project that they present at the annual Science and Engineering Fair.
3. As part of the *Science and Engineering Day*, EHA students guide small groups of middle school students through the Science and Engineering Fair hosted at the high school and explain the various projects on display. The high school students help their younger peers understand the science behind the projects as well as the process of conducting a scientific experiment from conception to presentation. The EHA students speak about their interests in

science and engineering, the courses they are taking in high school, their experiences in the EHA program, and their plans for college.

4. *The Science for Life Program* has developed and implemented age-appropriate, relevant, and interest-provoking educational modules for elementary students. Each module is composed of a series of lessons that use the research of the BMES ERC as a focal point to make science relevant to the young children. The lesson plans are taught by USC faculty and students together with EHA high school students. This affords the opportunity for engineering practitioners to go directly into the classroom and serve as mentors and role models to the elementary school children.
5. *Family Science Discovery Day* demonstrates to parents and other extended family members what the children have been learning in the *Science for Life* modules. Held on the USC campus, Family Science Discovery Day engages the entire family in STEM discovery activities that are informative and fun and reinforce the idea that learning is a family matter.
6. The *Engineering Medical Therapeutic Technologies Research Experience for Teachers (EMT^2-RET)* program supports the involvement of high school and community college STEM teachers in engineering research focused on medical therapeutic technologies conducted in laboratories at USC. Through participation in cutting-edge research at USC, teachers gain advanced knowledge of engineering. Additionally, teachers participate in professional development workshops that aid the teachers in the translation of the EMT^2-RET experience into relevant classroom curricula and activities.

Potential Applications

Most K–12 students have limited opportunities to directly interact with scientists, engineers, or students who are planning to become scientists and engineers. Thus, the typical elementary and high school student frequently entertains misconceptions of what these professionals look like and what they actually do. To address this situation, the BMES ERC outreach program has made mentoring a central tenet and has interwoven mentoring throughout each of its outreach components. The mentoring conduit begins with senior BMES ERC faculty researchers and proceeds through the university, high school, and elementary school levels. Individuals from one educational level serve as mentors and role models to the next level, thus establishing a culture of connectivity that spans the full educational and professional spectrum. It is the goal of the BMES ERC education outreach initiative that dynamic involvement at all levels of the educational pathway will increase both the number and diversity of U.S. citizens becoming scientists and engineers.

For More Information

Visit http://bmes-erc.usc.edu.

NSF Engineering Research Center for Biorenewable Chemicals (CBiRC) Pre-College Education Program

Background

The National Science Foundation (NSF)-sponsored Engineering Research Centers (ERCs) are a group of interdisciplinary centers located at universities all across the United States, each in close partnership with industry. ERC innovations in research and education are expected to impact curricula at all levels, from pre-college to lifelong learning, and to be disseminated to and beyond their academic and industry partners. A vital part of ERC education programs are outreach efforts to bring engineering concepts to pre-college classrooms, with the aim of attracting students to engineering and STEM careers. Because ERCs play a critical role by integrating research, education, diversity, outreach, and industrial collaboration, the NSF views ERCs as change agents for academic engineering programs and the engineering community at large.

The Center for Biorenewable Chemicals' (CBiRC) pre-college education strategic plan is to form long-standing partnerships with central Iowa school districts and school districts located in relative proximity to CBiRC partner institutions. The pre-college program focuses primarily on grades K–12, with a mission to effectively impart in the next generation of students the relevance of the engineering profession, the skills required to succeed in this profession, and its value in our technological society.

CBiRC has partnered with the Des Moines School District, the largest and most diverse school district in Iowa (over 30,000 students, 63 schools, 49% underrepresented minority enrollment and over 60% students receiving free or reduced lunch). The partnership with the Des Moines school district was established in 2008 and included the district science curriculum coordinator, district school improvement leaders, district lead teachers, CBiRC pre-college staff, and staff from the National Commission on Teaching and America's Future (NCTAF). A needs assessment was conducted to determine obtainable objectives and goals.

Based on the needs assessment, a long-range vision was created to support the following:

- Science teachers to think and perform as 21st century scientists in their classrooms
- Professional learning communities for science teachers across disciplines, grades and schools
- Long-term partnerships between CBiRC and school districts to ensure best practices are maintained

Over the past five years, CBiRC has established effective STEM professional development opportunities for K–12 teachers, provided classrooms with resident scientists and engineers, created opportunities for middle and high school students to pursue scientific research, and participated in the creation of a highly successful STEM professional learning community across middle and high school grades.

For More Information

Visit http://www.erc-assoc.org/programs/about.
http://www.cbirc.iastate.edu/education/precollege/