Engineering Education Experience, E3, for teachers: a professional development workshop for 6-12 engineering education

Bette Grauer, Karen L. Roberts, Tom C. Roberts, Gary A. Clark, Amy Rachel Betz

Engineering Education Experience, E3, for Teachers: A Professional Development Workshop for 6–12 Engineering Education

Bette Grauer, Karen L. Roberts, Tom C. Roberts, Gary A. Clark, Amy Rachel Betz

Kansas State University

Engineering Education Experience, E3, for Teachers: A Professional Development Workshop for 6–12 Engineering Education

Abstract

This paper describes a professional development program developed for middle and high school teachers, counselors, and administrators designed to provide information about grades 6–12 engineering curricula, engineering career paths, the Kansas State University College of Engineering, and student preparation for the study of engineering. The program, Engineering Education Experience (E3) was developed at Kansas State University, a midwestern university with a comprehensive engineering college. The program was created to support the University Engineering Initiative Act (UEIA). The UEIA, approved by the Kansas Legislature in 2011, provides funding for the state's three engineering colleges to increase the number of engineering graduates in the state. In support of this plan, Kansas State University College of Engineering created E3 to inform 6–12 teachers, administrators and counselors of engineering as a topic of study and career path with the intent of reaching middle and high school students. The program was offered to teachers as a summer professional development workshop.

During the summer of 2012, the Kansas State University College of Engineering hosted two 3-day engineering education workshops for teachers. Topics of lessons and activities included (a) engineering design, (b) problem-solving, (c) biological and environmental engineering, (d) nanomaterials, and (e) wind power. Activities and discussions allowed teachers to extend their knowledge of STEM topics and to meet with College of Engineering administrators, faculty, and students.

Sixty-six teachers, counselors, and administrators participated in the E3 workshops. Participants included middle and high school math, physical science, biological science, and gifted teachers, along with counselors and administrators. Participants received 20 hours of professional development credit. A pre-workshop survey assessed their existing knowledge of engineering and what they hoped to learn from the workshop. Participants also completed a post workshop evaluation survey. A majority of the responses were favorable to the E3 workshop, with 98.5% of participants rating overall quality of the presenters/sessions as very good or excellent. Participants indicated satisfaction in presentations of the many areas and applications of engineering, variety of programs, and careers associated with engineering, and engineering-related activities for the classroom. This paper includes discussion topics and lesson plans developed for the E3 program and used during the workshop, including hands on and collaborative activities related to biological and environmental engineering, nanomaterials, and wind power.

Introduction

As a part of a plan to increase engineering graduates in the State of Kansas, the Kansas State University College of Engineering created a professional development program for middle and high school science and math teachers, administrators, and counselors. The University

Engineering Initiative Act (UEIA), passed by the Kansas Legislature on May 25, 2011, funded the professional development program. The professional development program was offered to teachers as a summer engineering education workshop. Teachers from across the state of Kansas were invited to participate in the workshop to learn about middle and high school engineering curricula, engineering career paths, the College of Engineering, and student preparation for the study of engineering. Teachers received 20 professional development hours and were eligible for one hour of academic credit. Travel, lodging, and meal expenses were provided along with a $500 stipend.

The University Engineering Initiative Act

In 2010, the Kansas Legislature called for an increase in the number of engineering graduates to stimulate economic development. Industry leaders in the state expressed a need for more engineers to support planned industrial expansion. According to the Center for Economic Development and Business Research, one engineering professional creates 1.78 additional jobs, and results in a 2:1 fiscal benefit to cost ratio.[8] Eighty percent of all science and technology-based occupations in the state stem from engineering and information technology fields.[4] The National Academies report that as much as 85 percent of measured growth in income per capita in the United States is due to technological advancements made by engineers.[9]

In response to this need, the State of Kansas passed the University Engineering Initiative Act (UEIA) in 2011.[7] The purpose of the act was to provide funding with required matching new funds from the institution for recruitment, retention, infrastructure, and faculty needed to create and support an increase in engineering students. State universities in Kansas committed to increase the number of engineering graduates by approximately 60 percent over a 10-year period. Kansas State University committed to increasing the number of annual engineering graduates by 160 over a 10-year period.[5]

Engineering Education Experience for Teachers

The Kansas State University College of Engineering created Engineering Education Experience (E3), a professional development program for middle and secondary school teachers in Kansas. The E3 program was offered as a teacher workshop during the summer of 2012, with a future offering planned for 2013. Two workshops were held, one on the Manhattan, Kansas campus and the other in Overland Park, Kansas at the Blue Valley School District Center for Advanced Professional Studies (CAPS). Teachers from across the state participated in the workshops. A total of 66 middle and high school math, physical science, biological science, and gifted teachers; administrators; and counselors attended the workshop. Through participation in E3, they gained information about engineering to share with students, parents, and fellow professionals. The program included information about various engineering disciplines and engineering career paths. Teachers participated in engineering lessons, hands-on activities, research presentations, and discussions on incorporating engineering into the classroom. They also visited engineering classrooms and labs to learn about research and engineering design. Engineering administrators presented information and fielded questions on preparation for the study of engineering as well as transfer credit and scholarship opportunities. Teachers completed pre and post surveys to determine their expectations and measure the success of the workshops.

Purpose of the Study

The purpose of this study was to understand the needs of the teacher participants, how they responded to the program information and activities, and how they planned to use the information in their classrooms. Results and conclusions were needed to determine the efficacy of this workshop and guide future engineering education workshops. This report includes information from a pre-workshop survey, description of the workshop, discussions with teachers, and a final evaluation survey.

Research Questions

Overarching questions for this study included the following:

- What did teachers wish to gain from the workshop?
- What knowledge of engineering did teachers bring to the workshop?
- What information did teachers gain about engineering in their classrooms and school settings?
- What were continuing concerns for teachers in sharing information about engineering with students, families, and co-workers?

Conceptual Framework

Education literature identified engineering as an important interest area for K–12 education.[2, 3] Several factors accounted for this interest, beginning with the opportunity to integrate academic content with engineering design. There was a focus on developing student interest in science and mathematics to encourage more students to enter the engineering pipeline. Besides the idea of introducing students to the field of engineering, there was interest in helping all students understand how engineering impacts our world.[1, 3]

The primary challenges for K–12 engineering were to (a) determine where in the curriculum to incorporate engineering, (b) define K–12 engineering content, (c) create an understanding among stake holders of the importance of engineering education, and (d) prepare teachers to successfully teach engineering.[2] One way to address these challenges was to provide engineering education professional development for K–12 teachers. Many did not have background knowledge or experience to integrate engineering concepts and information into their classroom teaching. K–12 teachers were educated for specific, discrete content; i.e. science, mathematics, and technology. Preparation and professional development were necessary for the teachers to have knowledge and accompanying confidence to bring engineering concepts into the classroom.[2]

Professional development in K–12 engineering represented change in content and pedagogy.[2, 3] It required learning best practices, teaching techniques, and design principles; integrating mathematics and science; and collaborating with colleagues in other disciplines. To incorporate the concept of design, teachers needed to rethink activities in the classroom as they facilitated open-ended design experiences to solve real-world problems. Preparing K–12 teachers to provide authentic engineering activities in their classrooms required integrated mathematics and science applications, along with exposure to engineering design.[3] Learning engineering related activities and collaborating with other STEM teachers allowed teachers to think more like an engineer —

analytically, critically, and reflectively.[3] Professional development resulted in secondary teachers gaining knowledge and skills to transfer this new learning into the classroom and school setting. Teachers identified effective professional development as including hands-on activities, teacher collaboration, and instructor credibility.[3]

Method of the Study

This report was developed as a cohort study to learn the needs of teachers in the area of engineering education and to evaluate the efficacy of a workshop developed to meet those needs. Data was collected in the form of pre and post surveys and notes from collaborative discussions. The data was analyzed for common threads and emerging themes.

E3 Program Development

Engineering administrators, department chairs, faculty, staff, and K–12 teachers developed the E3 program. Collaboration began with an initial discussion of the needs of the university in conjunction with the UEIA. The workshop team determined a need existed to increase understanding of the field of engineering, engineering careers, and high school student preparation for the study of engineering, along with an understanding of engineering mathematics and research. A pre-workshop survey was developed to gain input from teachers. The survey was designed to gather demographic and teaching background information from teachers. In addition, the survey gathered teacher interest in the workshop, prior engineering knowledge, and expectations for the workshop. The pre-workshop survey is presented in Appendix D.

Pre-workshop Survey Results

Teachers were asked why they wished to participate in the E3 workshop. The majority of responses indicated a desire to learn how to bring engineering into their classroom and prepare students for engineering. When asked their prior knowledge of engineering, teacher answers varied. Many had been engineering students prior to switching to education in college. Two teachers had worked as engineers prior to entering the field of education. Seventeen of the teachers said they knew nothing about engineering. Some teachers had participated in Kansas State University engineering events, had attended other engineering workshops, or had worked with engineering education programs and competitions. Several of the teachers had family members with engineering careers.

Teachers were asked what they wanted to gain from the workshop. The variety of answers were organized into the following categories: (a) activities and knowledge for teaching engineering in the classroom, (b) knowledge of the field of engineering, (c) career information and opportunities, (d) information about Kansas State University College of Engineering, and (e) how to prepare students for academic success in engineering. The pre-workshop survey responses and needs identified by the team guided development of lessons, activities, and discussion.

Pre-workshop Survey Findings

The pre-workshop survey indicated that teachers recognized the need for knowledge of engineering. In addition to wanting classroom teaching activities, teachers wanted information that would allow them to guide their students to careers in engineering and prepare students for academic success. The findings confirmed that teachers were willing and effective partners in increasing the numbers of engineers as desired by the College of Engineering and the authors of the UEIA.

Curriculum Development

The curriculum was planned and implemented to allow participants to better understand the field of engineering and related careers, the College of Engineering at Kansas State University, and how to introduce engineering education into classrooms and school settings. A goal of engineering education is to develop collaboration and problem solving skills while building topical knowledge.[10] The lessons and activities created for the workshop supported that goal. Topics included (a) engineering design, (b) problem solving, (c) biological systems and environmental engineering, (d) nanomaterials engineering, and (e) wind power, with emphasis on integration of science and mathematics. These topics were selected based on responses in the pre-workshop survey of teachers, needs of the College, and engineering research at Kansas State University. Activities and discussions were planned to allow the teachers to extend their knowledge of STEM topics and better understand engineering disciplines, the college curriculum, support services, preparation for engineering, and career opportunities. The workshop took place over three days. Agendas are shown in Appendices E and F.

Administrators and department chairs provided information about the College and participated in group discussions. Department chairs shared information about their specific departments. Faculty and students presented information on bioengineering and nanomaterials. These presentations provided the participants a look at ongoing engineering research in the College of Engineering. Staff and students shared hands-on lessons related to wind energy and nanomaterials. Biology researchers and engineering staff presented lessons and activities related to biological systems and environmental engineering, engineering design, and collaborative problem solving. The participants also toured the Manhattan campus and observed the Engineering and Science Summer Institute, a program for high school students.

Participants

Sixty-six teachers and counselors participated in the E3 workshops, including 25 males (38%) and 41 females (62%). The percentage of male and female participants was different than the percentage of male and female engineering students enrolled in the College of Engineering. Undergraduate enrollment for the 2011–2012 academic year had 3056 students with a gender breakdown of 14% female and 86% male.

Workshop participants were from schools with enrollments ranging from 40 to 2000. This is representative of the span of enrollments in high schools and middle schools across the state. Ten participants were from schools of 40 to 200 enrollment, 33 participants were from schools with enrollment of 200 to 800, 11 participants were from schools with enrollment of 800 to 1200, and 12 participants were from schools with enrollment of 1200 or greater. Teachers represented many years of experience in secondary education. Seventy-six percent of the participants had taught more than 10 years, with 12% teaching between 5 and 10 years, 11% teaching between 3 and 5 years, and 1% had taught less than 3 years. The teachers who attended the Manhattan workshop represented 21 school districts across the state. Education disciplines represented and the numbers of teachers in each were (a) physical science – 13, (b) biological science – 10, (c) mathematics – 12, (d) gifted education – 3, (e) counselors – 2, and (f) Project Lead The Way – 1. The Overland Park workshop participants represented 12 school districts, mainly in the northeastern part of the state. They represented the following education disciplines: (a) physical science – 8, (b) biological science – 7, (c) mathematics – 9, (d) middle school math and science – 8, (e) counselors – 1, (f) gifted education – 1, and (g) administration – 1.

Collaborative Discussion

Guiding questions developed collaborative discussion with the participants. Graduate students took notes of discussions and captured specific responses and emerging themes. During the opening session, teachers were asked to share their understanding of what engineering is. Responses to this question included specific activities such as construction, bridges, and reverse engineering. Some responses were more general with perceived description of engineering, to include problem-solving, design, varied subject, project-based, exactness and detail-oriented, and technical.

After lessons and presentations about nanomaterials and bioengineering research, participants responded to the following questions:

1. What made an impression on you?
2. What did you learn about engineering?
3. What can you take back to your classroom/school setting?

Participants discussed the questions at their tables and reported their results to the rest of the group. Teachers were impressed with the presentations on engineering research and learning about the connection between engineering research and their topics of instruction. They learned that engineering requires collaboration, interaction, and communication skills, and that these activities provide motivation for learning. They enjoyed learning about what faculty and students do in the College and appreciated the opportunity to converse with faculty and students. Teachers reported that they considered the information they had learned about engineering careers particularly important for sharing with their students. They also considered it important to take engineering topics and activities connected to science and mathematics back to their classrooms. There was some concern about being able to transfer the information to the classroom because of the advanced level and lack of resources.

Following an afternoon of engineering activities, lessons, discussion of the design process, and problem solving, discussion was guided by the following questions:

1. How can engineering fit into your classroom/school setting?
2. How can we partner with you in your classroom?
3. How can you promote engineering in your school after this workshop?

Participants discussed these questions in small groups and shared their results with the large group. To bring engineering into the classroom, teachers suggested that engineering design and challenges along with collaboration and problem solving should be included in the curriculum. In considering partnering with the college, teachers appreciated the opportunity to work with faculty. They were interested in how prepared their high school students were to study engineering and what they could do to improve that preparation. Teachers suggested bringing faculty and professional engineers into their classrooms as role models, particularly women faculty to encourage young women to consider engineering. They suggested that the college could bring in-service training to schools to reach their colleagues. To promote engineering in their schools, they discussed the need to expose students to engineering careers and the many disciplines of engineering. Teachers considered it important to describe engineering as a way to help people. They also considered it important to help students overcome fear of technical aspects of engineering.

Lessons

Lessons developed for the workshop introduced three important areas of experience for engineering education, (a) engineering design, (b) engineering mathematics, and (c) engineering modeling.

Engineering design is an iterative process, which begins by identifying a problem or need, followed by analyzing the need and developing a solution that solves the problem or meets the need. The process is iterative in that multiple solutions may be proposed, examined, and tested before the process is completed. Constraints may be provided by the project owner or may be determined by the engineer. Engineering design may lead to development of a solution or may lead to development and understanding of new engineering problems.

Engineering mathematics is the integration and application of mathematics and science with judgment gained from study, experience, and practice to solve problems or fulfill a human need. Engineering mathematics emphasizes application of mathematics rather than theory. The use of mathematics in engineering may be in the form of rapid estimating or precise calculations. In either case a thorough understanding of mathematics is critical for success in engineering.

Engineering modeling is the creation of visual or physical models simulating form, appearance, or function of engineered objects to facilitate testing and enhance further study, use, or design. Modeling may be in the form of sketches, graphics, prototypes, structural models, and mock-ups. Models may be scaled up as in the macro representation of micro size objects, or may be scaled down as in small scale buildings used to represent a city.

Each of these forms of engineering is accompanied by analysis, discussion, brainstorming, practice, and modification, and each is used in real world engineering practices. Lessons and activities developed in these areas create appropriate experiences needed to develop and guide understanding of the topic along with practice making assumptions and understanding constraints to guide problem solving and design.[10]

Key lessons created for the workshop were Biological Systems Engineering, Wind Energy and Power, and Nanomaterials Engineering. These lessons were developed to meet the expectations of the teachers while providing experience in each of the three areas of engineering. They also represented areas of research in the college. Each lesson was based on engineering challenges experienced by professional engineers. The lessons provided engineering activities related to topics in 6–12 biology, chemistry, physics, and mathematics. Lesson plans are included in Appendices A, B and C.

Biological Systems Engineering – Engineering Design

The biological systems engineering lesson presented engineering design and included collaborative problem solving activities. The lesson plan was written in 5E format.[11] The workshop team determined that a critical need for engineering education is to develop lessons and activities for biology teachers. In secondary schools, only a portion of the students take physics classes, but nearly all secondary students will take one or more biology class. This lesson was developed to address the need for engineering activities for a biology class.

A fictional scenario was introduced in which a small community planned to build a gas turbine power plant to support new businesses in the area. The community and the planned power plant were located within the Flint Hills Legacy Conservation Area in Kansas. A gas turbine power plant was required because the conservation plan for the area prohibited wind turbines due to endangered species adversely affected by the presence of towers. In this type of engineering challenge, the biological systems engineer is uniquely qualified to address the needs of the community while creating designs to meet the constraints of the conservation plan and maintain the integrity of the ecosystem. For this lesson the teachers assumed the role of biological systems engineers in creating a design to address one of the issues in the conservation plan.

For the design problem, the human need was a power plant for a community. Constraints were the requirements of the conservation plan to preserve the special ecosystem of the location. A teacher researcher with experience in Flint Hills ecosystem research presented information on the Flint Hills Conservation area. Information included maps of the area, rare biological systems within the area, and keystone species. Teachers were asked to examine aspects of the conservation area, select one requirement of the conservation plan that the proposed plant would affect, and create a design that would mitigate resulting environmental problems.

Wind Energy and Power – Engineering Mathematics

The wind energy lesson represented an engineering mathematics activity through integration of science, mathematics, and engineering practice. Teachers worked with small wind generators and calculated the power and efficiency of the generators. KidWind® Mini turbines were provided for this activity. Teachers assembled the turbines and connected multimeters. Small fans were used to provide wind and teachers worked with different fan speeds and positions to change current output. The facilitator led the teachers through calculations of power and efficiency of the turbines using blade lengths, wind speeds, and the Betz limit. An extension of the activity included creating and testing a wind farm designed to produce the most efficient locations for each turbine. Constraints included the available wind speed and maximum and minimum distances for the turbines.

Nanomaterials and Engineering – Engineering Modeling

This lesson utilized engineering modeling to allow teachers to experience and understand properties of nanomaterials using macro models. This lesson was created and presented by faculty from the Mechanical Engineering department to introduce superhydrophobic surfaces created by nanofibers with polar properties introduced into materials. Engineering faculty presented relative sizes and examples of macro, micro and nanomaterials. For the engineering modeling activity, the lesson presented a macro model of nanomaterials using polystyrene, toothpicks and ping-pong balls. The polystyrene represented the base material, while the toothpicks represented nanofibers. Ping-pong balls represented water droplets. Toothpicks were inserted into the polystyrene to represent nanofibers that repelled water droplets from the surface of the material. Participants used their materials to create a model demonstrating how the nanofibers kept water from the base material surface. To observe hydrophobic properties, teachers placed droplets of water on Teflon® squares and noted the shape of water drops on the surface and movement of the droplets across the surface when the square was tilted. Teachers made micro and nanochannels on the surface of the Teflon® using fine sand paper and placed water drops on the surfaces again, observing the change in shape and movement of the water. Teachers also examined the scratches under a hand lens and microscope to gain a sense of the micro and nanoscale of the scratches. The microscopic view showed that the sandpaper had not only created channels, but also raised ridges and spikes on the surface. At the macro level, the surface was still smooth. Discussions followed about uses of micro and nano channels on surfaces and how the observed properties could be engineered.

Evaluation

Evaluation of the workshop was completed through an assessment questionnaire at the end of the workshop. The assessment contained questions with a rating from poor to excellent. Additional questions required a short answer response. The assessment indicated that a majority of the participants responded favorably to the E3 workshops. Results of the assessment showed that 98.5% of participants in both locations rated the overall quality of the presenters/sessions as very good or excellent. Further, 86.4% found the usefulness of the program content very good or excellent, 92.4% rated the consistency of the program to its publicized content very good or excellent, and 93.9% rated the degree to which the program met their expectations very good or excellent. The assessment questions, tabular results, and responses to short answer questions are provided in Appendix G.

Findings

Evaluation responses and collaborative discussion on engineering education were analyzed for emerging themes. The analysis indicated that the information most valued by the teachers was information that helped them understand what engineering is, the types of engineering disciplines, and careers in engineering. The second most valued area was engineering applications and the cross curricular nature of engineering. Teachers also valued information about the College of Engineering. Demonstrations, with opportunities for teachers to learn about research applications, contributed to their understanding of the College. Overall, teachers responded favorably to presentations and discussions with engineering faculty and staff. While many teachers indicated a limited knowledge of the study and practice of engineering, the workshop allowed them to develop relevant knowledge for middle and secondary engineering education. Collaborative group discussion facilitated by engineering faculty and staff allowed secondary teachers to develop an understanding of engineering concepts, applications, and methods of bringing those ideas to their classrooms. Collaboration also allowed teachers to experience collaborative problem solving and encouraged them to develop creative solutions. Lessons relating engineering to secondary science and math curricula with hands-on activities helped teachers understand the study and field of engineering. Participants shared their satisfaction with learning engineering related activities for the classroom, including specific information on bioengineering, nanomaterials, and wind energy. Inviting the teachers to share how they would use the experience and activity in their classrooms generated enthusiasm and made them an integral part of the overall process of developing future engineers.

Applications of Findings – Recommendations for Engineering Educators

The intent of this paper was to present the results of the study and to provide an informative guide for engineering educators to develop similar workshops. The results indicate that schools of engineering can be effective venues for teacher professional development in engineering education. While hands on applications relating science and mathematics to engineering should be a part of teacher professional development, teachers indicated that they valued understanding the nature of engineering. A well-constructed professional development opportunity can allow teachers to quickly develop knowledge of the field of engineering. Attention should be given to creating lessons and activities that help teachers understand the field of engineering and the opportunities in engineering that they can share with their students. Teachers are interested, active learners and respond favorably to this type of workshop. It is important that they be treated as partners in meeting the challenge to increase numbers of engineering graduates. The knowledge that they gain in a professional development workshop ultimately will be transferred to their students. A successful engineering education teacher workshop can contribute to increased numbers of students interested in pursuing degrees in engineering. More importantly, an effective workshop can contribute to the development of students who are prepared for the requirements of the study of engineering and able to translate that preparation into academic success.

Future Research and Improvements

E3 workshops will be conducted again in 2013. Using information from this study, plans will be created to meet the needs of Kansas State University and the participants. Changes to the program for 2013 include more discussion of engineering applications and new lessons and activities that create an understanding of engineering disciplines. Teachers will have more opportunities for interaction with staff, administration, and students.

Continued evaluation of the E3 workshops will be included in the overall evaluation for UEIA. It will be important to plan the workshops to meet specific needs of high school and middle school teachers, and to provide activities applicable to different fields of engineering. As the Kansas State University College of Engineering continues to provide teacher professional development, it will be important to consider opportunities for more interactions between participants, faculty, staff, and students.

Bibliography

1. Baine, C. (2004). *Is there an engineer inside of you? A comprehensive guide to career decisions in engineering*. Professional Publications: Belmont, CA.

2. Custer, R. L. and Daugherty, J. L. (2008). Professional development for teachers of engineering: Research and related activities. In C. M. Vest (Ed.). *The Bridge: Linking Engineering and Society.* (Vol. 39 no. 3, pp. 18–24). Washington D.C.: National Academy of Engineering. Retrieved from http://www.nae.edu/Publications/Bridge/16145/16204.aspx
3. Daugherty, J. L. (2010). Engineering professional development design for secondary school teachers: A multiple case study. *Journal of Technology Education*. 21(1), 10–24. Retrieved from digitalcommons.usu.edu
4. Kansas Board of Regents. (2011, October 19). *Kansas Board of Regents minutes, October 19-20, 2011.* Retrieved from http://www.kansasregents.org/resources/PDF/1690-JOct19-20,2011Minutes.pdf
5. Kansas State University College of Engineering. (2011). *University Engineering Initiative Act*. Retrieved from http://www.engg.ksu.edu/ueia
6. New K–12 science framework incorporates engineering. (2011, October). *PE: The Magazine for Professional Engineers*. Retrieved from http://www.nspe.org/PEmagazine/11/pe_1011_Communities_Education.html
7. Kansas Board of Regents. (2011, March 25). *Regents applaud Senate's approval of engineering initiative.* http://www.kansasregents.org/regents_applaud_senate_s_approval_of_engineering_initiative
8. Center for Economic Development and Business Research. (2009). *Economic and fiscal impact of engineering professionals in Kansas and analysis of proposed increase in university funding for engineers.* Retrieved from http://webfiles.wichita.edu/cedbr/EngFINAL.pdf
9. Committee on Prospering in the Global Economy of the 21st Century. (2008). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington D.C.: National Academies Press. DOI ISBN-10: 0-309-18758-3
10. Grauer, B. and Grauer, D. (2010, June). *Automobile emissions: A problem based learning activity using the Clean Air Act.* Proceedings of American Society for Engineering Education Annual Conference and Exposition, Louisville, Kentucky. Washington D.C.: ASEE. Retrieved from http://www.asee.org/search/proceedings
11. Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A. & Landes, N. (2006). *The BSCS 5E instructional model: Origins, effectiveness and applications, Executive summary.* Colorado Springs, CO: Biological Sciences Curriculum Study. Retrieved from *http://www.bscs.org/bscs-5e-instructional-model*

Appendix A – Biological Systems Engineering

Biological Systems Engineering
Kansas State University
5E Format

Purpose: To actively involve students in biological considerations of a site plan for a proposed natural gas electrical power plant near a conservation area and wildlife refuge and to employ engineering design to address the need within the constraints of the conservation plan.

Background: Environmental Protection Plans are developed to protect the habitat and organisms in a biome. When construction occurs in or adjacent to sensitive or protected areas, it is the responsibility of the engineer to address the environmental protection plan with engineering design solutions. For example, the engineer may need to design protective fencing to safely keep protected species out of a project site, addressing the movement characteristics of the organism. Or, the engineer may design a water treatment system to prevent release of contaminants and maintain optimal temperatures of water released into the area.

This lesson was developed from real world experiences of engineers who have designed engineering solutions to meet environmental protection and conservation plans. The case study was developed for students who live in communities near the Flint Hills Legacy Conservation Area (FHLCA) and the Flint Hills National Wildlife Refuge (FHNWR) in eastern Kansas. The lesson can be adapted to other regions.

Lesson Goals: (1) Learn the connection between engineering and biology topics. (2) Learn the role of the biological system or environmental engineer. (3) Use collaboration and problem-solving to create an engineering design.

Objectives

1. Analyze the needs of human society from an economic standpoint.
2. Analyze the requirements of a healthy habitat in a specific biome.
3. Examine the needs of the native organisms found in a specific habitat.
4. Discuss the potential impacts of human needs on the organisms around them.
5. Develop an engineering design to meet the needs of both humans and the habitat.

Engage

"For the last several class sessions we have been talking about different kinds of biomes, the organisms found in them, and what organisms need to survive. As a concluding activity for our unit, we are going to address a case study where all this information comes together, and we have to make some decisions and come up with a plan to address the needs of humans while considering the environmental impact those needs cause. One specific biome we talked about was the grasslands/prairie."

Discussion questions

1. What do we know about the prairie abiotic factors (temp, precipitation, climate, altitude)?
2. What are some examples of organisms found in a prairie habitat? (grasses, few trees, birds, mammals, reptiles, amphibians, mussels, insects, etc.)
3. What would happen if we removed one or more of these organisms or abiotic features from this habitat?
4. What if we drained a river, or rerouted it somewhere else? Or removed all the hawks from the area? What consequences do you think might occur?

Explore

"For our work today, we are focusing on an area in eastern Kansas— the Flint Hills Legacy Conservation area and the Flint Hills National Wildlife Refuge. It surrounds the Neosho River and abuts the John Redman Reservoir." (Show map)

Using Internet resources, find out more about this wildlife refuge, the habitats it contains, and the organisms that depend on that habitat. (teams of 2-4 students)

Environment features

Abiotic

- Bodies of water
- Geology/soil
- Seasons

Organisms

- 5 plants with pictures
- 10 animals with pictures — birds, mammals, reptiles, fish, amphibians, insects, mussels
- Any endangered or threatened species in the area
- Other unique biotic factors

Collaboration

Create a document/list of the information you find to share and discuss with your peers.

Explain

1. Students will discuss the features found relating to the FHWR and FHLCA.
2. Show the maps and how the area is a small part of a larger Ecoregion (Arkansas/Red River watershed, and Tallgrass Prairie Ecosystem)
3. Provide other examples of plants/animals in the area and the threatened and endangered species found on the refuge.
4. Show students the main points of the conservation plan of the FHWR so they know the specific goals of the refuge and can use that information to build their plans in the next phase of the lesson.

Elaborate – Engineering Challenge

"One of the hardest parts of protecting the environment is balancing the needs of people with maintaining a native habitat. Economics (money) often wins out over the environment. What we want is to find a way to have both."

Provide information about the role of biological systems and environmental engineers, and how their work maintains the integrity of environmental conservation and protection plans.

Case Study

"For this case study, we have created a fictional scenario in which a community near the Flint Hills Wildlife Refuge (FHWR) wishes to build a power plant to support jobs in the community."

The residents of Hartford, Kansas, a small community near the FHWR, the Neosho River, and John Redmond Reservoir wish to build a power plant for their community to provide power for industry and economic growth. The region is primarily a cattle-grazing area, and the Hartford residents wish to support the location of a meat production plant in their community to create a market for the cattle-grazing industry and provide jobs for residents of their town. An immediate need for the production plant is economical electrical power. The town leaders have studied other community owned power plants in the state and have determined that building their own power plant will be the most economical and beneficial way to provide power. While the plant will not be in the FHWR, it will be near the area and in the Flint Hills Legacy Conservation Area (FHLCA). The residents are determined to meet the requirements of the conservation plan in construction and operation of the power plant. Wind turbines are not allowed in the area because some bird species will not nest within site of the towers. The community has determined that a gas-fired plant will be the best option.

As the biological systems engineering team for the company, it is your job to identify and address one issue you identified as being important to maintaining the FHWR and help it reach its conservation goals. You will need to explain WHY this issue is important and must be addressed. It will cost more money (usually), so your reasoning must be sound and strong.

Example

The plant requires water for its operation. How can the plant obtain enough water to do what it needs to do without affecting the flow of the Neosho River or the John Redman Reservoir? i.e. create a cooling pond. What do they do with the water once they have used it and why is it important to address this issue? i.e. build a water treatment facility. Which species or habitat could be affected by this issue? i.e. fish, amphibians.

Note: Help students identify manageable issues to address and develop a plan. Have student teams pick which part of the problem they will work on.

Evaluate – Engineering Challenge

Preparation

1. The students will study existing power plants and determine characteristics of a power plant that may affect species or habitats in the area.
2. Students will find information on wildlife buffer zones built around power plants in the state.
3. The students will study the Flint Hills Wildlife Refuge and the Flint Hills Legacy Conservation Area.
4. Students will identify the needs of species and habitats in the area and how they might be affected by a power plant.

Design

1. Student groups will select an issue to be addressed with an engineering design and present it to the class.
    a. Create a mind map or other presentation method to demonstrate the issue or problem identified.
    b. Identify the constraints that the issue presents.
    c. Explain why the issue is important with evidence and strong reasoning.
    d. Explain the plan to address the problem (what are they going to do to "fix" it).

2. The students will create a design and an engineering model of the design that will address and provide a solution to the issue or problem identified.
    a. Students will present their design to the class, using their model.
    b. Explain how it creates an engineering solution to the identified issue.
    c. Identify any directives for the design that must be followed during construction and operation. i.e. fences to keep organisms out during construction, removal of debris during and after construction, access roads for construction.

Appendix B -Wind Turbine Energy and Power

Wind Turbine Energy and Power

Purpose: To demonstrate the function and operation of a wind turbine and learn wind power calculations.

Introduction: A wind turbine transfers mechanical energy from wind to an electric generator, converting mechanical energy into electrical energy. The turbine absorbs the wind energy by slowing down the wind as it passes through the blades. This activity calculates the power available from wind based on the wind speed, the power available to the turbine using wind speed and blade diameter, and the power generated using current and voltage. Design of a wind farm is included as an extension activity.

Materials
KidWind® Mini Wind Turbine
Multimeter
50 ohm resistor
Wind speed meter
Small 8”, three-speed fan.
Ruler
Paper for calculations
Calculator
Safety glasses

Safety: Wear safety glasses while assembling and operating the wind turbine. Keep hands away from the spinning blades.

Procedure

1. Assemble the mini wind turbine.
2. Measure the diameter of the blades in meters and calculate the area occupied by the spinning blades. Record on calculation page
3. Place the fan approximately 0.5 m in front of the turbine and turn it on to maximum speed. Adjust the position of the turbine until it spins.
4. Using the wind speed meter, determine the wind speed before and after the turbine. **Caution: Wear safety glasses. Keep hands and face away from spinning blades.** For each side of the blades find the maximum wind speed. Record on calculation page.
5. Attach the multimeter to the turbine connectors at the base. Measure the voltage and current. Consult the KidWind® directions for correct measurement of voltage and current. The mini turbine requires a 50 ohm resistor for proper measurement of current. Record on calculation page.
6. Calculate wind power, turbine power, and generator power.

Assumptions

1. Transfer of kinetic energy from the wind to the blades causes the blades to spin.
2. The mass flow rate of air through the turbine blades is conserved, i.e. the amount of air mass going into the blade area is the same as that going out.
3. The density of the air remains constant, and there is no heat transfer from the rotor to the flow or vice versa.
4. The power generated is constrained by the Betz limit. Only a portion of the energy of a wind stream can be extracted while still allowing continuous flow. To extract all energy from the wind would require that the speed after the blades dropped to zero. The power coefficient (C_P) represents this limit (Figure 1).

Definitions and Values

Area, A is the circular area occupied by the spinning blades.
Density, ρ is the density of air at NTP (20°C, 1 atm) = 1.205 kg/m^3
Wind speed, v in m/s is measured before the blades and after the blades.

v_1 = wind speed before blades
v_2 = wind speed after blades

Available wind power, P_W = power available from the wind based on the wind speed before the blades.

$$P_W = \frac{1}{2} * \rho * A * v_1^3$$

Turbine power, P_T = power developed by transfer of kinetic energy from the wind based on the wind speed after the blades and the power coefficient, C_p.

$$P_T = C_P * \frac{1}{2} * \rho * A * v_2^3$$

Output power, P_O = electrical power generated by the turbine based on current, I, and voltage, V, of the generator.

$$P_O = I * V$$

Power Calculations

1. Using the ruler measure the blade diameter and calculate the area that will be occupied by the spinning blades. **Caution: Wear safety glasses. Keep hands and face away from spinning blades.** Find the wind speed before and after the rotor and the ratio of wind speeds.

   A = _____________

   v_1 = _____________

   v_2 = _____________

   v_2 / v_1 = ______________

2. Calculate the Available Wind Power, P_W = power available from the wind based on the wind speed before the blades.

$$P_W = \frac{1}{2} * \rho * A * v_1^3$$

Be careful to record and take units into account. The unit for power is the Watt (W).

$$1 \text{ W} = \frac{1 \text{ N–m}}{\text{s}} = \frac{(1\text{kg} * \text{m/s}^2)\text{–m}}{\text{s}} = \frac{1 \text{ kg–m}^2}{\text{s}^3}$$

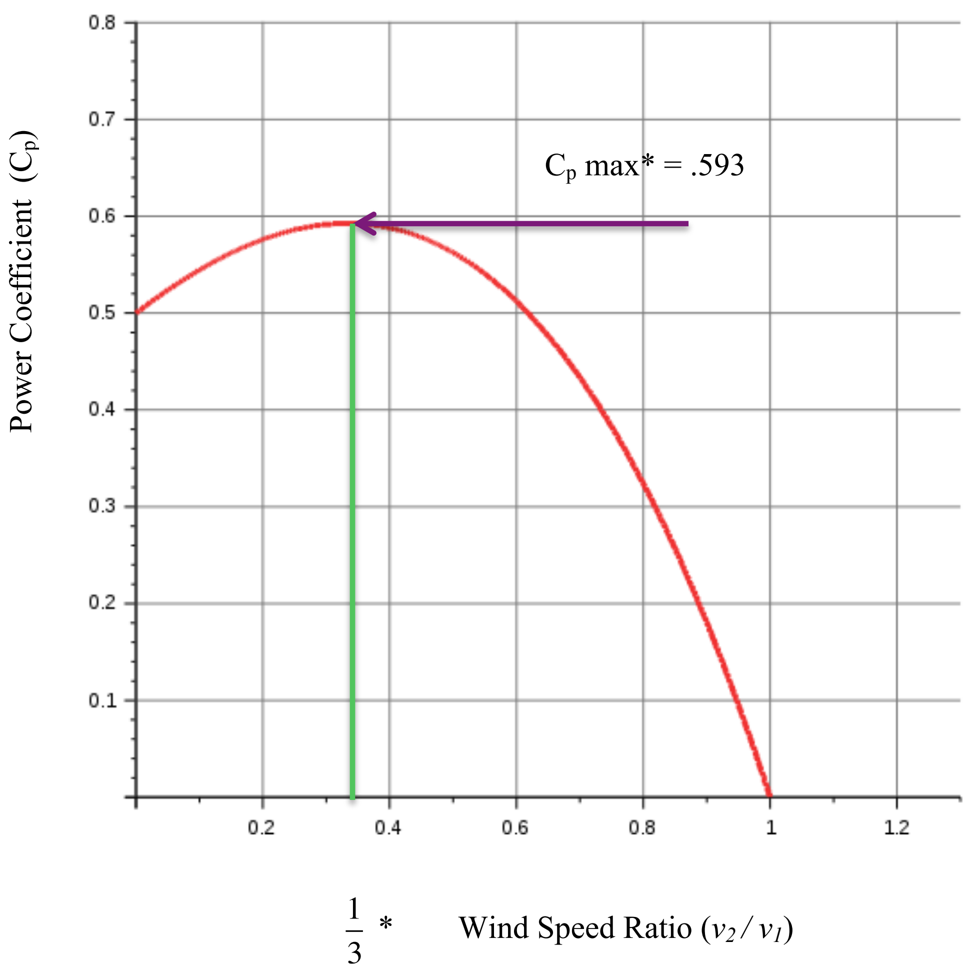
Density of air, ρ at NTP (20°C, 1 atm) = 1.205 kg/m^3

3. Using Figure 1, find the power coefficient, C_p.

C_p = _______________

Figure 1

Power Coefficient vs. Wind Speed Ratio



* Maximum power coefficient occurs when $v_2 / v_1 = 1/3$
Note: As the wind speed ratio approaches 0, the power coefficient is not valid.

4. Calculate the turbine power, P_T, using the wind speed after the blades and the power coefficient, C_p.

$$P_T = C_P * \frac{1}{2} * \rho * A * v_2^3$$

5. To calculate power output, P_O, of the wind generator, measure the current and voltage produced by the wind turbine. Consult the KidWind® directions for correct measurement of voltage and current. The mini turbine requires a 50 ohm resistor for proper measurement of current.

$$P_O = I * V$$

Where I = current in Amperes and V = Voltage in Volts

I = ________

V = _______

6. The efficiency of the turbine is the power output, P_O, from step 5 divided by the available wind power, P_W, from step 2.

$$\text{Efficiency} = P_O / P_W$$

Questions

1. Is the power output, P_O, higher or lower than the turbine power, P_T ?

2. Why is there a drop in power output below the turbine power?

3. Most turbines are at best 35% to 40% efficient. Do your calculations support this claim?

4. What types of changes can be made to improve the efficiency of a turbine?

5. What is the maximum power output of a large commercial wind turbine?
    a. What is the maximum power of a power plant that supplies your community with electricity?

6. What are some engineering challenges associated with existing wind turbines?

Extension – Engineering Design: Designing a Wind Farm

Combine with three other groups and create a wind farm. Your instructor will give you a maximum area for your farm. Design your wind farm for maximum efficiency of your turbines.

a. Experiment with different locations and elevations for the turbines and measure the wind speeds before and after each turbine.

b. After your design is completed, conduct a final test and present your design and measurements to the class.

Appendix C – Nanomaterials and Engineering

Nanomaterials and Engineering
Kansas State University

Purpose: The purpose of this lesson is to introduce students to nano scale materials and engineering. This lesson will demonstrate how nanofibers make materials superhydrophobic.

Background: Engineers engaged in research on micro and nano scale materials developed this lesson. At the micro and nano scale, macro properties of materials change from those that students study and experience.

Prelab activity: After a brief discussion of nano, micro, and macro scale, direct students to research types, properties, and uses of nanomaterials.

Materials:

Part 1
- Polystyrene (Styrofoam) sheets, 6"x 6"x 0.5", one per student
- Toothpicks, six per student
- Ping-pong ball, one per student
- Hand lens, one per student

Part 2
- Water and stain resistant nanofiber infused fabric, 6" x 6" sheet for each student
- Measuring syringe, one for each student
- Beaker with water

Part 3
- Teflon® sheets cut in to 2" squares, one for each student
- Fine grade sandpaper cut into 1" squares, one for each student

Procedure

Part 1

In this part of the activity, you will create an engineering model of nanomaterials using macro materials to simulate how nanofibers make superhydrophobic surfaces. The polystyrene represents fabric and the toothpicks represent nanofibers. The ping-pong ball represents a water droplet.

1. Place the polystyrene on a table and drop the ping-pong ball from 12 inch height.
2. Place the ping-pong ball on the polystyrene sheet and tilt it in different directions observing how the ball rolls off.
3. Using the toothpicks as nanofibers, find a way to keep the ping-pong ball from touching the foam. Observe how the ping-pong ball rolls off the toothpicks.

Part 2

In part 2, you will use nanofiber infused materials to observe the behavior of water on the material.

1. Using the syringes, place droplets of water on the nanofiber infused material and observe properties of the water. Does the water bounce off the surface? Does the water soak in or bead up?

2. Tilt the material to allow the water to roll off. Does the water roll off easily or hold its position?

Part 3

In part 3, you will create nano and micro channels that affect the properties of water on a surface. When the surface is scratched with the sand paper, nano and micro ridges and spikes are raised off the surface and create water repellent properties.

1. Observe the surface of the Teflon® square with a hand lens and microscope.
2. Place droplets of water on the Teflon®, observing how it beads up and rolls off.
3. Using the sand paper scratch the surface of the Teflon® to create nano and micro channels.
4. Observe the surface with the hand lens and a microscope.
5. Place droplets of water on the scratched surface and observe how the water behaves.

Questions

1. How can you use the properties of nanofibers to make materials or surfaces with special properties?

2. What types of uses could you imagine for these materials?

3. From your research on nanomaterials, what are some of the properties that make nanomaterials valuable?

Extension – Engineering Model

1. Describe other engineering models.

2. Create your own engineering model to demonstrate other engineered objects. Your model can be a macro model of a small object or a scale model of a large object. It can be a three-dimensional or two-dimensional diagram.

3. What properties are demonstrated by your model that could not be understood without it?

Appendix D – Pre-Workshop Survey and Responses

Pre-Workshop Survey

1. Name: ____
2. Gender: _______________________________________
3. School: ____
4. Approximate school size (number of students): ___________
5. Primary content area: ________________________________
6. Subjects taught: _____________________________________
7. Years of teaching experience: _________________________
8. Why do you wish to participate in the Engineering Education Experience Teacher Workshop?
9. What knowledge of engineering do you bring to the workshop?
10. What types of information do you hope to gain from this workshop?

Pre-workshop Survey Responses to Question 10: Teacher Expectations Grouped by Topic

What types of information do you hope to gain from this workshop?

2. Activities and Knowledge for Teaching Engineering in the Secondary Classroom
   - Incorporate engineering practices into curriculum
   - Manipulatives for the classroom – hands-on activities
   - Classroom activities that relate to engineering
   - Real-world application
   - Understand STEM education
   - Classroom activities related to engineering
   - Relate to common core state standards
   - Gain ideas of engineering practice that can be incorporated into K-12 science curriculum
   - Same for specific sciences and math
   - Interesting project ideas for math
   - Game plan for how to improve lesson planning and to overcome the lack of resources
   - Innovative techniques that can be used to develop interests of students to explore and build on concepts they learn in class
   - Completed lesson plans
   - Integration of design and engineering
   - Practical real-world applications
   - Focused ways to implement engineering in the classroom that align with core standards
   - Cross-curricular projects
   - Contacts for networking
   - How to develop problem-solving skills
   - Creativity and critical thinking
   - Engineering process
   - Where gifted students can go to learn about engineering

- Help students see their role in the future as engineers
- Help students see relevance of math and science in engineering
- Help other teachers in district
- Learn new vocabulary

3. Knowledge of the Field of Engineering
   - Different types of engineering
   - Strengths/interests beneficial to engineering
   - Connection with agriculture background of students
   - Knowledge of alternative energy
   - What does the day of an engineer look like? i.e. hours, activities, travel, use calculus, communication, teamwork
   - Experimental design process
   - Clearer vision/understanding of engineering

4. Career Information and Opportunities
   - Potential careers for students
   - Information about specific jobs
   - What is job outlook, currently and in future?
   - Career opportunities
   - Specific duties of engineering types

5. Information about Kansas State College of Engineering
   - Opportunities for teachers to work with Kansas State
   - Opportunities for students and parents with Kansas State
   - Specific degree programs and what is involved
   - Scholarship programming
   - Increased knowledge of Kansas State College of Engineering

6. How to prepare students for academic success in engineering
   - Classes to take for preparation
   - Opportunities available for high school students
   - How to motivate female students
   - Are they ready for second course in calculus?
   - Help students see benefits of engineering education and career.
   - How to better prepare students for rigor of college
   - Academic skills
   - Skills and knowledge needed for students wanting to enroll in engineering

Appendix E – Manhattan Agenda

Kansas State University College of Engineering
Engineering Education Experience, E3 for Teachers
Manhattan, KS
May 30 – June 1

Wed, May 30

Check in	4:00 – 5:00

Dinner
5:00 – 7:00
Introductions,
Welcome, Overview of workshop
UEIA, need for engineers

Thurs, May 31

Coffee	8:00 – 8:30
Introductions, plans for the day; What is engineering?	8:30 – 9:00
Group #1: Nano/micro engineering, *RA 3034* Group #2: Bioengineering, *RA 2064*	9:00 – 10:20
Break	10:20 – 10:40
Group #1: Bioengineering, *RA 2064* Group #2: Nano/Micro Engineering, *RA 3034*	10:40 – 12:00

Lunch
12:00 – 1:30
Department Chairs
Discussion of the Morning Activities

Electrical Energy/Wind Turbines/Math Application	1:30 – 3:00
Break/Group picture at 3:30	3:00 – 3:30
Discussion of engineering design and problem-solving	3:45 – 4:15
View student projects from summer engineering camp	4:15 – 4:45

Dinner
5:30 to 7:00
Focused Discussions

Friday, June 1 – *Carter Learning Center*

Coffee	8:00 – 8:30
Discussion – Preparation for Engineering, Support for Teachers	8:30 – 9:15
Biological systems Engineering Lesson	9:30 – 11:45
Break	10:30 – 10:45

Lunch
11:45 to 12:30
Discussion of the Morning Activities

Tours	12:30 – 1:30
Wrap-up, Survey, Payment forms Professional Development Certificates	1:30 – 2:00

Appendix F – Overland Park Agenda

Kansas State University College of Engineering
Engineering Education Experience, E3 for Teachers
Blue Valley CAPS, Overland Park
June 20-22

Wed, June 20 – *CAPS, Overland Park*

Check in 4:00 – 5:00

Dinner
5:00 – 7:00
Introductions

Thurs, June 21 – *CAPS, Overland Park*

Coffee, Introductions, Plans for the day 8:30 – 9:00

Physical Science/Math Teachers
Wind Energy Activity/Electrical Grid/Bottle Rocket 9:00 – 11:30

Biology Teachers – Bioengineering Technology 9:00 – 11:30

Lunch
11:30 – 12:30
Discussion of the Morning Activities

Group Picture & Discussion; Design process 12:30 – 1:30
CAPS E3 staff – Teaching Engineering Design, and problem-solving

Water Treatment/Electric Grid visits 1:30 – 4:00

Close – Discussion of tours, Plans for Friday 4:00 – 4:30

Dinner on your own

Friday, June 22 – *Kansas State University College of Engineering, Manhattan*

Coffee, *CAPS, Overland Park*	7:30 – 8:00
Bus trip to Kansas State Manhattan Campus	8:00 – 10:00
Welcome, refreshments (*Carter Learning Center*)	10:30 – 11:00
Tours of Engineering Complex	11:00 – 12:00

Lunch (*Carter Learning Center*)
12:00 – 1:00
UEIA, need for engineers

Tours	1:00 – 1:30

Wrap-up, Survey, Payment forms, 1:30 – 2:00

Travel to Overland Park	2:00 – 4:00

Appendix G – Workshop Assessment

Workshop Assessment

Questions

Participants responded to questions 1 – 5 on a scale of poor, fair, good, very good or excellent. Results are shown in Table 1.

1. Quality of presenters/sessions
2. Usefulness of the program content to your needs
3. Consistency of the program to its publicized content
4. Degree to which the program met your expectations
5. Overall the length of sessions: too short, just right, or too long.

Participants provided short answer responses to questions 6 – 9.

6. What new or helpful information did you learn in the workshop?
7. What information will you take with you to use in your classroom?
8. What was the most valuable information that you received?
9. How can we improve the workshop?

Table 1 – Results of Questions 1 – 4

Assessment Item	Number of Responses				
Manhattan Workshop	Poor	Fair	Good	Very Good	Excellent
Overall quality of the presenters/sessions				11	23
Usefulness of the program content to your needs		1	3	8	22
Consistency of the Program to its Publicized Content			1	3	30
Degree to Which the Program Met your Expectations			2	8	24

Assessment Item	Number of Responses				
Overland Park Workshop	Poor	Fair	Good	Very Good	Excellent
Overall quality of the presenters/sessions			1	15	16
Usefulness of the program content to your needs		1	4	14	13
Consistency of the Program to its Publicized Content			4	11	17
Degree to Which the Program Met your Expectations		1	1	13	17

Responses to Assessment Questions 6 - 9

Similar responses are grouped together with numbers of teachers shown in parentheses.

6. *What new or helpful information did you learn in the workshop?*
    a. An understanding of the many areas and applications of engineering. A ‘picture’ of what engineering is. How engineering is tied to different disciplines. Different professions and careers associated with engineering. (33)
    b. Several hands-on experiments to incorporate in the classroom. (10)
    c. Update on Kansas State College of Engineering. What students need to be successful at Kansas State. Tour of Kansas State engineering facilities. (6)
    d. Learned about bioengineering. Never thought of these things as being part of engineering. Got some wonderful ideas of how to use biology synthesis and tie it to Chem II concepts. Web sites available for lessons. (6)
    e. Information to help advise students about college, and to be able to discuss engineering career paths with them. (6)
    f. International Genetically Engineered Machine (iGEM) and bioengineering. (4)
    g. Engineering applications lessons.
    h. Kansas State wants students to succeed and has support services in place for students who need them.
    i. Students need to take math (calculus) – it is the bottleneck. Good to know if they do not take calculus, it’s not the end of the world.
    j. Networking with other teachers and engineering faculty to exchange ideas, opportunities, and needs was the most helpful information in this workshop.
    k. Definition of engineering as opposed to math/science.

7. *What information will you take with you to use in your classroom?*
    a. Applications for integrating engineering into all of the curricula. Ideas for cross-curricular projects. Better prepared to introduce all students to education and guide students interested in engineering. Engineers are in high demand and the types of jobs are so varied that there is something for almost everyone. (21)
    b. Information on areas of engineering students might be interested in. Career awareness. (11)
    c. Information about enrollment, requirements, scholarships, degree programs, AP credit etc. Recruitment information for Kansas State COE. (8)
    d. Engineering design process. (5)
    e. Plan to use the wind farm activity in my classroom. (5)
    f. Math preparation and to what extent that will help me prepare students for engineering. Will also help with math practices for CCS (common core standards). (3)
    g. More collaborative work. (3)
    h. Help for students. Ideas for ways to present topics that help students understand engineering concepts. (2)
    i. Collaboration with Kansas State faculty and peers. Recruiting information for Kansas State. (2)
    j. How engineering and science work hand in hand. Educate students on how these disciplines apply and are relevant to real life.

8. *What was the most valuable information that you received?*
    a. To know the diversity of areas in engineering. Information about the field of engineering. Career opportunities. Understanding the importance of engineering in our lives. (17)
    b. Visits with the department heads and what they feel are needed to prepare students. Kansas State faculty members are awesome – committed to the students. Depth and breadth of engineering college. Campus tours of engineering departments – meeting department chairs and faculty. (13)
    c. Activities to take back to the classroom. Resources for integrating more STEM. Practical applications. Free resources. Ways to instruct students with new learning activities. (11)
    d. Information about preparing students for success in the engineering program. Schedule of events for next year will be helpful. (9)
    e. Networking with other teachers. (6)
    f. Everything . . . the best-organized, most efficient, ultimate power-packed, warmest reception conference I perhaps have ever attended. This will impact our students and families, our staff, and our school!
    g. Loss of fear of the word, engineering. Helpfulness of faculty and their desire to see students succeed.
    h. Value is most measured by how effectively I can help my students be successful. Also it is very valuable to me to know people I can now ask questions of and refer students to.
    i. Bioengineering power plant project.
    j. Understanding the strengths to look for in students to encourage them to consider engineering.
    k. Overall awareness of engineering and a new way of 'viewing' what we do in the high school classroom.
    l. Wind energy activity.

9. *How can we improve the workshop?*
    a. Difficult to come up with anything — loved staying in the hotel rather than a dorm room! Food was great! All the individuals who spoke with us are wonderful and so easy to approach. Great to have university people as connections and future reference. Good size. (14)
    b. Hands-on mathematics activities. More math applications. Different tour for mathematics teachers. (10)
    c. Separate high school and middle school teachers. Would have liked more activities specific to middle school classroom. (6)
    d. More activities to take back to my classroom but what I did get was very good. More real-world ideas for engineering in the classroom — have teachers pre-submit lesson plan ideas to collect and share at the workshop. More information as to how we (teachers) can acquire skills and knowledge to implement more STEM based and more engineering specific curriculum and activities to our classes. Expand the curriculum with tie-ins to help keep students interested in science and math. (6)
    e. More time for tour. More information from computer science, architectural, and industrial. (2)

f. More small groups with professors from each department. (2)
g. Enjoyed hearing about current engineering grad student research — more from the students! Have a section on what research is being done within the departments. (2)
h. More brainstorming/group discussion. (2)
i. Excellent job in following through the schedule. Speakers and logistics were on the dot. However, workshop might have been too packed.
j. Need longer time for tour of campus and engineering facilities.
k. Some presentations were a little too technical for what I teach.
l. Wish for ongoing collaborative mechanism.
m. Would like more in-depth instruction into actual engineering practice.
n. Personally, I disliked the activities that we did — but enjoyed the presentations of the students and professors. This gave me more information that I can take back to my classroom.
o. More time in the labs.
p. More about chemical engineering.