What's an Engineer? Teaching Teachers about Engineering

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Abstract

Many K-12 teachers do not know what an engineer does or what the different engineering disciplines are. Consequently, they are unsure of how to encourage their students to explore engineering as a career. To address this issue, a three day workshop was held during the Summer of 2001 at Michigan Technological University. During this workshop, teachers attended exploratory sessions where they completed hands-on experiments that pertained to specific engineering disciplines. The explorations covered Biomedical, Chemical, Civil, Electrical, Computer, Environmental, Geological, Materials, Mechanical and Mining Engineering. Each session lasted about 1 1/2 hours and included a brief synopsis of that engineering field. Most of the hands-on experiments could be directly used or adapted for use in K-12 classes. Some of the explorations were: constructing a soil resistivity meter, modeling oxygen uptake in a lake, mechanical dissection of a toaster, removal of solids from water using reverse osmosis and bridge design using West Point Bridge Designer software. At the end of the workshop, the participants completed an evaluation form. Most self-reported very little knowledge of specific engineering disciplines prior to the workshop. After the explorations, they reported a significant increase in their knowledge of the different disciplines. This paper describes the activities performed by the participants in the workshop and presents evaluation results. Lessons learned and future plans will also be presented in this paper.

Introduction

Most K-12 students learn about engineering as a career choice from what their parents or teachers tell them. Teachers encourage students who are good at math and science to go into engineering. Many teachers have difficulties communicating to their students what engineers do because they do not know enough about engineering (i.e. types of jobs and career paths, engineering disciplines). To address this issue, Michigan Technological University developed a 3 day workshop to introduce K-12 teachers to various engineering disciplines. Teachers learned about engineering through hands-on activities, many of which were usable in their classrooms.

Workshop Structure

For this workshop, teachers attended sessions that introduced them to Mining, Environmental, Civil, Mechanical, Biomedical, Geological, Electrical, Computer, Materials and Chemical Engineering. Engineering faculty from the various engineering departments developed and presented the sessions to the K-12 teachers. In addition to these sessions, teachers were shown how a remote Scanning Electron Microscope (SEM) could be used in their classrooms. Each

session was 1 1/2 hours. The teachers were given a brief description of an engineering discipline and completed a hands-on activity to illustrate an engineering concept/application or to demonstrate what that type of engineer could do. The sessions were designed such that the teachers would attain a bse level knowledge of the disciplines such that they could guide their students in the selection of an engineering career. For example, teachers that used the Mechanical Engineering activity in their classrooms could tell students who enjoyed dissecting common household appliances to explore Mechanical Engineering as a career choice. Futhermore, teachers who attended this workshop could give the student a basic definition of a given engineering disciplnes and then contact the Michigan Tech presenter for more infromation about that field. Many of the activities were ones that the teachers could use in their classrooms. Table 1 shows the itinerary for the workshop.

Table 1: K-12 Typical Teacher Workshop Itinerary

Time	Wednesday	Thursday	Friday
8:30-10:00	Introduction/Icebreaker	Mechanical Engineering	Electrical Engineering
10:00-10:30	Break		
10:30-12:00	Mining Engineering	Biomedical Engineering	Computer Engineering
12:00-1:00	Lunch	Remote Microscope Demo	Lunch
1:00-2:30	Environmental Engineering	Picnic Lunch; Geological Engineering	Materials Engineering
2:30-3:00	Break		Break
3:00-4:30	Civil Engineering		Chemical Engineering
Evening		Banquet at Keweenaw Mountain Lodge followed by Sunset Cruise on Lake Superior	

Discipline Explorations

Each faculty presenter developed an appropriate session for the K-12 teachers. These sessions ranged from working on computer simulations to conducting engineering experiments and studies. A summary of each exploration is given in the following.

Mining Engineering:

With the intent of offering an overview of the mining/minerals industry, the session addressed the Mining and Mineral Process Engineering curriculum, potential careers, and a demonstration using a computer to model an ore body. The teachers were introduced to the various phases involved in exploration, development, and the operation of a mine. Images were shown of the various phases of a particular project. A CD of these images was sent to the teachers so they could introduce their students to mining engineering.

Environmental Engineering

Environmental engineers deal with both natural (e.g. atmospheric, aquatic, terrestrial) and engineered or constructed (e.g. water and waste treatment) systems. This exploration considered an engineering approach to lake management intended to improve water quality and promote a healthy environment for aquatic life. Bench scale testing and mathematical modeling of gas transfer and hypolimnetic aeration were conducted as an example of one technique used to restore polluted lakes. An overview of the field of environmental engineering was provided, including fields of endeavor and opportunities in employment and graduate education.

Civil Engineering

This session introduced teachers to the structural design of truss bridges. They learned about different bridge types, with an emphasis on truss bridges, and what keeps them from falling down. After the introduction to bridges, they used a computer software program to design a truss bridge (West Point Bridge Design (http://www.dean.usma.edu/cme/outreach/WPBD/wpbdhome.htm)). They also received a brief introduction to the field of Civil Engineering, including areas of study, jobs, and salary ranges.

Mechanical Engineering

To many K-12 teachers, Mechanical Engineering is the discipline that they think of when they think about engineering. This field of engineering deals with how mechanical objects work and interface with other engineering disciplines. To illustrate how things work, the teachers were given different common household objects to disassemble (or dissect). The teachers were divided into small groups and dissected different objects, including: a toaster, a hair dryer, an electric iron, and a radio. The teachers were asked to look at the mechanical components and to describe how they worked. Then they were asked to look at how electrical engineering and mechanical engineering interfaced in the device via the power cables, connectors and circuit boards. The purpose of this activity was to show what mechanical engineers do when they design an object and how other engineering disciplines affect mechanical design.

Biomedical Engineering

Polymers, or just plain old plastics, comprise many medical devices that people take for granted. Devices such as hip replacements, contact lenses, and artificial hearts all have polymers in them. Participants learned what polymers were and about their unique properties. They discussed medical devices, and participated in hands-on experiments that could be taken back to the classroom. These experiments included “Making GAK” (http://www.transman.org/gak.html) and the Viscoelasticity of Cheese. The teachers were shown a number of hands-on devices (a bone cement mixer, and several total joint replacements) to illustrate how engineers design them, and the design limitations that occur because these devices are inside the body.

Remote Microscopy for Classroom Applications

The SEM has become a key instrument for observing characteristics of both natural and man-made materials. K-12 students can learn much about the physical structure of materials and insects by viewing them through an SEM. Due the expense of an SEM and because it requires a skilled technician to operate, most K-12 schools cannot afford this type of equipment. Therefore, many universities with SEM’s are creating programs where K-12 teachers can send specimens to a lab where the technician loads the specimen into the microscope. Students can

then control the specimen viewing through an Internet hook-up. After the viewing and analysis are completed, the images and data are downloaded to the user. Michigan Tech is working with area schools to set up this type of program. The University of Illinois at Urbana-Champaign (http://bugscope.beckman.uiuc.edu) already has a program set up and running. The purpose of this exploration was to introduce K-12 teachers to this program so that they could use it in their schools.

Geological Engineering

To show how geological engineers locate ore deposits and how they can be measured, teachers constructed a simple resistivity meter using 9 volt batteries and a voltmeter. They used this device to locate an ore shoot at a nearby copper mine. Resistivity is one of several, commonly used geophysical techniques. It measures the changes in subsurface by measuring the changes in the soil resistivity. For this session, it was used as an exploration tool to locate the top of the ore zone at a local copper mine. Resistivity is used in mineral exploration and it also has implications for groundwater modeling, characterization of groundwater contaminant plumes and for finding and locating shallowly buried objects. These latter applications make this an extremely important tool for engineers involved in environmental assessment and cleanup. For the petroleum engineer, these measurements are critical for the characterization of potential oil and/or gas producing units.

Electrical and Computer Engineering

Computer Engineering is the exciting world where computers interface with the outside world. In this introduction, participants investigated one such interface, that of a computer and a telephone keypad. Participants programed a Digital Signal Processor (DSP) chip to generate the proper tones to dial a phone when the keys on the keypad were depressed. The teachers also learned that a DSP is a special purpose computer designed to work with sounds or other signals.

Materials Engineering

The purpose of this demonstration of Materials Engineering was to examine the effect of cooling rates on the mechanical properties and microstructures of different types of steels. Teachers examined two steels: a low alloy (1040) steel commonly found in cheap bike frames and a 4140 steel that is used in quality bike frames. Steel specimens of each alloy were water quenched and air cooled, and the resulting hardnesses were measured. A set of specimens from these steels plus a furnace cooled (annealed) specimen of each alloy were available for examination by optical microscopy. As part of this discussion, they also examined the structure of welds in steels since this is the primary means by which a bike frame is constructed from the individual tubes.

Chemical Engineering

Chemical Engineering is a broad field of study integrating the sciences of applied chemistry, thermodynamics, fluid flow, and material processing. A serious challenge facing coastal dwelling populations is providing an affordable supply of potable water. As these municipalities continue to draw down ground water supplies faster than natural aquifers can replenish them, wells backfill with brackish water. A recent advancement in membrane technology has created a cost-effective solution to this problem – a process called Reverse Osmosis. In this

encounter with Chemical Engineering, an inexpensive water purification unit (a hand-held water filter) was used to desalinate water. The water purity was measured and the throughput and energy requirements were calculated. A Reverse Osmosis unit was then designed to supply drinking water to a small village in a remote part of the world. This problem is scalable and open-ended and will challenge the creative abilities of any group of students from kindergarten through college seniors. This problem could be presented as a simple demonstration and taste test or as a complete design project. Abundant web references are available by searching for keywords: reverse osmosis, and desalination.

Participant Comments

Throughout the workshop, the nine participants provided verbal feedback regarding the sessions and at the end of the workshop, they completed a written evaluation of the workshop. In this evaluation, the teachers were asked to rate each session and answer questions regarding the structure of the workshop. In addition, they were asked to rate their knowledge of each engineering discipline before and after attending this seminar series.

As shown in Table 2, most of the K-12 teachers rated the explorations high. On a scale of 1-10, the average rating of the nine engineering sessions was 9.0. More importantly, their understanding of a given engineering discipline increased significantly after they participated in the workshop. The average knowledge of a given discipline prior to the workshop was 3.4. This increased to 7.6 after they completed the explorations. This means that these teachers are more capable of explaining the various engineering disciplines to their students. It also means that they will be able to direct their students to select an engineering career based on what the student is interested in - not just because the student is good at math and science. For Biomedical Engineering, a relatively new and rapidly growing field, the teachers showed a 4 point gain in knowledge after the workshop. Many of the teachers stated that they knew that Biomedical Engineering was a career choice for their students, but they did not know which students would enjoy going into that field. After they completed the exploration, they said they could tell their students what biomedical engineers design and do.

Many of the teachers provided constructive criticism. Because this was the first time the workshop was held, these comments were extremely important. As shown in Table 2, the teachers enjoyed the explorations and learned a great deal about engineering through participating in the activities. The negative comments mostly centered around the length of the sessions. The participants would have liked more time to talk with the presenters and/or spend more time on a given experiment. They suggested that the session be increased to two hours where the activity would last 1 1/2 hour and there would be a half hour for discussion and/or more experimentation.

Table 2: K-12 Teacher Workshop Evaluation Results (Based on a scale of 1 - 10)

Session	Overall Rating	Knowledge of Discipline		Typical Comment
		Pre	Post	
Biomedical Engineering	8.9	4.3	8.4	"Lots of info about what Bio Med Eng's do and experiments are very usable and adaptable to various age levels."
Chemical Engineering	9.6	3.4	7.9	"Slide show information about career. Water filter experiment very interesting." "... this would be a great experiment to do in the class room."
Civil Engineering	9.0	4.9	8.1	"Using the knowledge that was shared with us in an application - Bridge Building. Gave me many ideas to apply in classroom."
Electrical/ Computer Engineering	8.4	2.8	6.4	"Great real life application of the mathematics of sinusoidal waves."
Environmental Engineering	8.9	3.9	7.8	"We simulated a real-world environmental problem and were able to see the analysis of the data."
Geological Engineering	8.3	1.9	6.3	"Field Trip- measure of delta V - resistivity test to find an anomaly which would indicate a mineral deposit."
Materials Engineering	9.4	2.8	7.9	"Discussion and experimentation showing strength and toughness factors of materials."
Mechanical Engineering	9.3	4	8.3	"Building the Lego car and taking apart the toaster were fun. I had never looked inside a toaster before. I don't think females are ever exposed to these types of activities (very rarely anyway)."
Mining Engineering	9.4	2.6	7.4	"Making everything in terms that we (with our lack of experience) could begin to understand and be excited." "The software program he showed us to model ore deposits and where to place the shafts was awesome."
Overall Average	9.0	3.4	7.6	

The participants also commented on the overall structure of the workshop. Some of their comments are listed below:

- "It would be nice if we could earn a credit from MTU for attending. A good addition would be to have each participant bring in one activity or lesson that they developed that works well. It is awesome to get ideas form others. This program is excellent. Thank you!!! The background

education was excellent on each type of engineering, but maybe it would be nice if a high school/elem. school application could also be offered for each engineering field."

- "Expand but keep groups small (more people attend, but break into section that rotate through sessions.) Provide summary info on working / job conditions of different type of engineers. Opportunities available. Continue! Continue! Continue! I know several people who would attend if this was repeated next year. All the extras really made a difference."
- "Continue the program - Expand the program to four or five days. Give more time to complete and review experiments. MTU possibly giving college credit for the week participants - share lessons they would use in their classroom. This was an excellent program. I have gained immensely these three days. Lots of ideas that can be adopted to my classroom. This gave me an excellent start. Hope I can continue to glean ideas and knowledge from the faculty in the future. Thank you very much. WOW!"

As shown by these comments, this program was very well received by the teachers. They enjoyed the hands-on experiments and the descriptions of the various engineering fields. They also gained ideas and knowledge that they could apply to their classes. Verbally, many commented on how friendly and helpful the faculty presenters were. Many of them requested copies of experiments they completed at the workshop. Several of the participants have communicated that they have incorporated lessons learned in this workshop to their classrooms.

Most of the teachers recommended that the participants receive college credit for attending the workshop. They thought this would increase attendance at the workshop and get younger, less-experienced teachers to attend. (In Michigan, teachers must earn 18 college credits in approved programs every 5 years, or newly certified teachers need 18 college credits in approved programs or a Masters degree within 5 years of graduation to maintain their teaching certificate.) They would also like to know more about starting salaries, where jobs are available for a given field and projected job opportunities.

Faculty Presenter Comments

After the workshop was completed, the faculty presenters were asked to comment on how their session went and what they thought of the participants and workshop. Overall, the comments were positive. All of the faculty commented on how interested the teachers were in the sessions and the specific engineering disciplines. They were impressed with the questions the teachers asked and the interest they had in learning more about a given experiment and an engineering discipline. Like the teachers, they would have liked the session length to be increased so that each session could include a discussion period. A typical faculty comment was: "They (the teachers) were interested in what was presented and eager to learn about engineering. They were also very creative in that they were brainstorming ideas about how to bring things back to their classrooms while they worked the activities."

Plans for Summer 2002

K-12 Engineering Workshop is planned for late July, 2002. Teachers will receive a Continuing Education Unit (CEU) for participating in the three day program. The time for each session will increase to two hours. This will permit more time for discussions and additional experimentation.

Teachers will be given handout materials that include web sites and experimental procedures. These materials will reduce the time required for teachers to include the workshop material in their classes. There will be a discussion period included at the end each day of the workshop to allow the teachers and faculty presenters to meet and further explore different experiments and activities.

Conclusions

K-12 teachers want to learn more about engineering. To facilitate this learning, a 3-day workshop was held at Michigan Tech in the Summer of 2001 where K-12 teachers went to explorations to learn about Mining, Environmental, Civil, Mechanical, Biomedical, Geological, Electrical, Computer, Materials and Chemical Engineering. These sessions included presentations and hands-on activities to show teachers what engineers do and how some of these activities could be used in their classrooms. The teachers left knowing more about engineering - and wanting to learn more. They have been incorporating some of what they learned into their classrooms. The teachers wanted to receive credit for attending the workshop and to have the workshop sessions last longer. The workshop will be held again in the Summer of 2002. To incorporate the participants suggestions, the sessions will last 2 hours and Continuing Education units (CEU's) will be earned.

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