ENGAGING HIGH SCHOOL TEACHERS IN ENGINEERING RESEARCH: OUR EXPERIENCE

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Abstract — During the summer of 2002, the College of Engineering at USF implemented a research experience for high school and middle school teachers, aimed at making engineering accessible to students at an earlier level. This paper reports the experience of one such teacher-faculty member pair from the group. The teacher participated in a research project to improve the placement of utility distribution systems routed along the transportation right-of-way. The individual selected had interests at the society/technology interface, and a background in American history. The teacher not only participated in the research study but also extended this engagement to include the cultural implications of the development of utility infrastructure. The principal result of this interaction has been the preparation and delivery of two extended lesson plans intended to introduce the subject of infrastructure technology to high school students in the context of history classes rather than traditional science/math instruction.

Index Terms — Engineering Education, High School, Infrastructure

INTRODUCTION

It is often true that young students have limited contact with engineering, and certainly there are few role models among their teachers in the K-12 years. During the summer semester of 2002, the College of Engineering at USF initiated and sponsored a project at the University intended to address this deficiency by bringing high school and middle school teachers into the research environment of the College for close involvement with several ongoing projects. Patterned after the NSF Research Experience for Teachers (RET) program, the ultimate goal of this seed endeavor was an integration of the experiences of these teachers and faculty into high school and middle school teaching, to promote a better understanding of technology at an earlier educational level.

During this first year, thirteen high school/middle school teachers participated and twelve faculty collaborators were directly involved. Most of these teachers came from schools in the immediate area around the University of South Florida in Tampa. Two of the authors (DDM and SCK) were paired as high school teacher and faculty collaborator. The remaining author (CAS) is the Associate Dean for Academics in the College and was directly responsible for the program. This paper is concerned with our experiences for this first year effort and additionally, we report on the interaction we have had inside the high school classroom.

The College had previously developed and conducted enhancement programs for high school students [1,2], but the effort reported here represented a significant step to involve teachers also. Hopefully, programs such as this will ultimately stimulate more interest in engineering as a profession.

ORGANIZATION OF THE PROGRAM

Most of the initial preparation for this program was handled by the Associate Dean for Academics within the College. Participating faculty members were asked to contribute about one-third of the cost of a stipend for each teacher-partner. In several cases where budgets were tight, special arrangements were made. As an added incentive, an arrangement was made so that teachers in the public school system could earn continuing education credit. The schedule for the program called for a preliminary organizational meeting, followed by a more formal welcoming session and joint meeting with all involved at the beginning of the program a few weeks later. For most of the teachers, the program was timed to coincide with the summer break although this interval did not work well for all involved (as was the case for DDM). Other arrangements were made to accommodate scheduling conflicts.

Each week several of the teachers delivered interim reports on their work to the whole group. The program finished with a banquet and the presentation of representative final reports. Each teacher submitted two lesson plans and involvement of the faculty mentor at the time when these plans would be implemented was strongly encouraged. The College program was judged to be an overall success. Most of the teachers had very positive experiences and were able to demonstrate significant development of lesson plans, classroom demonstrations and other means of transferring their experiences to the teaching environment.

THE RESEARCH TASK

A current research project, Utility Placement Along the Transportation Right-of-Way, Principal Investigators: S.C.

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Kranc and William Miller (funded by the Florida Department of Transportation), has as a principal goal to determine better ways to manage the corridor infrastructure. Historically, transportation corridors have been used jointly to accommodate a wide range of utility facilities (power lines, drainage, water, etc). A vast, crowded network has grown throughout the country to provide these services to the public. A deeper significance can also be associated with the utility corridor, as societal decision to accept a technological intrusion into the environment (for example utility poles). Such intrusion is not only an aesthetic and environmental issue, but also a potential hazard.

This project was ideal for joint participation between the faculty mentor and the teacher. In this case, the participating teacher was someone with interests at the society/technology interface, and a background in American and urban history. The unique background of the teacher contrasted with others involved in the program, having specialties in science and mathematics. The teacher was involved with this study for a period of about four weeks, during which time he became familiar the issues regarding utility locations. He assisted in investigating and developing an understanding of traditional practice regarding utility placement. This activity involved the examination of a variety of technical literature, as well as onsite investigation and the review of practitioner surveys (as part of the research team). While no special technical, scientific or mathematical skills were required, previous library research experience and Internet search techniques were extremely helpful.

During the program, the faculty member and the teacher became engaged in an extended study of the cultural implications of the development of utility infrastructure. Appropriate readings and related library searches were pursued as a second focus, and visual documentation became an important activity. The principal result of this interaction has been the development of two extended lesson plans (discussed below) intended to introduce the subject of infrastructure technology to high school students in the context of history classes rather than science/math instruction, as might be expected. These lesson plans are designed to actively engage the students in historical research and field exploration as group activities. Additionally, a paper focusing on the cultural aspects of infrastructure technology has been presented [3].

LESSON PLANS

1. Making Cities Work: How Engineers Transformed Late-Nineteenth Century American Urban Centers

Purpose and/or Objectives:

The purpose of this three-day lesson is to introduce high school American history students to the ways in which late-nineteenth century engineering advances in the field of utilities influenced urban growth, economic development, and municipal political reform.

This topic is important because it brings together issues that students usually view as unrelated, even though they are deeply interconnected. Utilities, and the engineering challenges and feats associated with them, both physically and figuratively unify the seemingly disparate issues of urban, political and economic growth, as well as social change. This lesson also introduces aspects of engineering—a discipline often absent in secondary school curricula, but ironically fundamental to understanding the development of the United States—into the study of American history.

Background and Major Concept(s) to be mastered during the activity:

Unit essential questions:

- What was it like to live in an American city 100 years ago?
- How did American cities function in the late-nineteenth century?

Students will understand that:

- Mid-to-late-nineteenth century American cities lacked most of the infrastructure found in today’s urban centers.
- Late-nineteenth century immigration and urban growth were not incited by realistic perceptions of American cities.
- Engineering-related changes to American cities fundamentally altered the manners in which they functioned.
- In order for utilities to be established, city governments needed to reform and assume broader responsibilities towards the public.
- Turn of the century technological advances and, later, New Deal engineering projects played major roles in transforming American cities into the spaces of today.

Skill(s)/Technique(s) developed in activity:

- Skills:
  - Analyze written and visual primary sources
  - Interpret statistical tables
  - Record data of current utility use
  - Theorize solutions to urban infrastructure problems

- Content:
  - Communicate the ways that public utilities changed late-nineteenth century American cities
  - Discuss the limitations of late-nineteenth century municipal political machines
  - Articulate how innovations in engineering impacted turn-of-the-century Americans
Materials needed:

- Primary sources mentioned in this lesson plan
- Computers with Internet access
- Pocket-sized notepad

Requirements from the students:

**Day One:**

Hook: Were mid-nineteenth century American urban centers really “cities on a hill?”

Uncovering students’ misconceptions often assists in the understanding of a new concept. Therefore, the lesson begins with students breaking into groups of three or four and articulating their perceptions of mid-nineteenth century American cities through the following two prompts:

- What did older (New York or Philadelphia) and newer (Chicago and Cincinnati) American cities look like around 1875? Try to describe the buildings, streets, and nearby waterways.
- What were overseas impressions of mid-century American cities? On what did future immigrants base their perceptions? How accurate were their views?

The groups reconvene to share their ideas with the rest of the class. Then the students are provided with primary sources (these can be adapted in accordance with a teacher’s available resources).

Students analyze a document individually, and then share their findings with another classmate who holds the same article. Possible questions to address when examining the primary sources include, but are by no means limited to:

- What is it, who made it, why was it made, who is the intended audience, what information does it provide, what information does it omit?

The groups then report their findings with the rest of the class.

From this information, the students then contrast their preconceived ideas of mid-nineteenth century American cities the particulars drawn from the documents. As a class, they then come up with a list of infrastructure elements that did not exist in urban areas 125 years ago.

**Homework:**

For the rest of the day, students are asked to keep an ongoing list of the utilities they use that would not have existed in New York or Chicago in the mid-to-late-nineteenth century. For the following day, they are to write a letter to their mayor, describing to him their daily life and asking him to consider implementing certain utilities, in order of perceived importance, that he could use his power to put install.

**Day Two:**

Hook: What was needed to expand the infrastructure of American cities?

Students read their letters to each other in small groups, and come up with the top five infrastructure elements they feel are most needed in order of priority. These are then shared with the entire class. With this top five list, the following two questions are posed:

- What will be required to address these needs?
- What will hold back the city from obtaining these services?

The class will then enter a discussion on late-nineteenth century political machines.

A concurrent explosive population growth of American cities compounded late-nineteenth century urban infrastructure issues. To introduce the topic of demographic influences, students will analyze the following population statistics:

- Official statistics from the top 100 American urban areas in 1800, 1820, 1840, 1860, 1880 and 1900. Focusing on the population growth for New York City and Chicago in the nineteenth century, students will determine the rate at which each city grew during the century. They will then ponder the following questions, aided with geographical maps of New York City and Chicago:
  - What infrastructure issues could New York and Chicago possibly face in common?
  - Could their infrastructure issues differ in any way? If so, how?

The class ends with the students learning about Chicago’s attempted solutions to provide the city with potable drinking water and adequate sewage disposal. The following websites provide useful visual aids:

http://www.chipublib.org/digital/sewers/history.html
http://www.chipublib.org/digital/sewers/history2.html

**Homework:**

Imagine yourself as the newly appointed Chief of Engineering in the city’s new Chicago Sanitary District. Your first responsibility is to provide the city with adequate sewage and clean drinking water. How will you modify the city’s current means of acquiring water and disposing of sewage? Before designing your solution, research the problems associated with Chicago’s water supply.

**Day Three:**

Students begin by sharing their engineering ideas with the class. The benefits and costs, potential successes and
failures are discussed. They then access the website http://www.chipublib.org/digital/sewers/history4.html to discover the means the city of Chicago took to reverse the flow of the Chicago River. The class reconvenes to discuss the following questions:

- Will this new design alleviate the city’s infrastructure problems?
- What other obstacles may emerge as a result of reversing the river’s flow?

Students go back to the Chicago Public Library on-line exhibition to discover what new problems were created by the Sanitary and Ship Canal.

The lesson is completed with the following question: if Chicago had so many problems implementing its utility infrastructure, and if turn-of-the-century cities across the country faced many similar unresolved problems, what needed to occur before these issues were addressed more effectively? Close with a hint at the role the federal government would take with all the New Deal projects in the 1930’s.

2. What is the Price of Progress?

Purpose and/or Objectives:

The ostensible purpose of this year-ending four-day lesson is to introduce high school American history students to the ways in which utilities deeply impact their everyday lives. However, the underlying purpose is not merely to make teenagers aware of the roles of utilities—instead, students will use the study of utilities to reflect upon these three essential questions:

- Do utilities bring us closer together or drive us further apart?
- Have advances in utilities transformed cities into “better” places to live?
- Are you willing to pay the social costs (encompassing political, environmental, and economic considerations) for the utilities you use?

These queries are important because they ask students to address an essential question that lies at the heart of all historical studies: is history a story of progress? Providing definitive answers to the aforementioned questions is not the ultimate goal of this exercise. Instead, it is of greater importance to make students consider the personal role they play in the creation of American history through their use of the country’s infrastructure. Another benefit of this lesson lies in its ability to bring history “alive” by encouraging students to take their study beyond a classroom’s walls. Finally, this lesson draws upon aspects of engineering—a discipline often absent from secondary school American history curricula, but ironically fundamental to understanding the development of the United States.

Background and Major Concept(s) to be mastered during the activity:

Students will understand that:

- Public utilities provide urban residents with both positive and negative social costs
- The everyday use of an urban utility infrastructure plays a large part in determining the manner in which a city will develop
- The study of history is not always one of continual improvement

Skill(s)/Technique(s) developed in activity:

- Skills:
  - Determine the location of utilities in a given urban space
  - Analyze the use of utilities in a given urban space
  - Track their everyday use of utilities

- Content:
  - Communicate the ways in which public utilities help and hinder the function of contemporary American cities
  - Analyze the social costs of contemporary American urban utilities

- Value:
  - Evaluate their philosophical standing towards utilities

Materials needed:

- Computers with Internet access
- Pocket-sized notepad

Requirements from the students:

Day One:

Previous night’s homework: Read Keating, Chapter One. Open the class with a discussion addressing the following questions:

- What is a utility?
- What constitutes contemporary public utilities?

Once the class has produced the major categories of utilities, ask students to reflect individually upon their yearlong study of American history and determine when each of these utilities both emerged and became commonplace on the public scene. They should then pair-off with a partner or two to compare their answers. Finally, the groups should come together to share their conclusions, and settle upon common answers.
Students will then be asked to look around their classroom and, quietly and on their own, write down all the utilities at work in the space. Findings are then shared with the class. Next, students repeat the exercise, but instead they use their school grounds to reflect on the placement and role of utilities.

The class will then brainstorm and take notes on the following questions:
- Who manages each of these utilities?
- Who pays for their installation and services?

Finally, students will choose one of the eight major utilities listed below as their focus of research for the next couple of days. Ideally, an equal number of students will be in each group. The utility study groups are:
- Streets
- Public transportation
- Water supply
- Sewer systems
- Solid waste disposal
- Power systems
- Telephone access
- Cable access

Homework:
- For the following three days, students will keep track of their use of utilities. Until the next class, students will choose one of the eight major utilities listed above and keep a log of each time they make use of this utility in the next 24 hours.
- Write a journal entry the following: describe a typical weekday in your life, from when you woke up to when you went to sleep, exactly as you currently live BUT imagine that you do not have utilities at your disposal. What would this day look like? Be sure to approach this assignment as objectively as possible. Try not to comment on the positive or negative implications of utility existence and use.
- Read Keating, Chapter Four.

Day Two:
Debrief as a class on the “utility log” kept for the past 24 hours. Students will begin researching their utility using available books, the Internet and/or other resources. During the next two days, students should consider the following questions:
- How has the development and expansion of this utility impacted city growth? How was urban life different before this utility was readily available?
- Does expanding this utility alleviate needs or produce greater demand?
- What are the social costs of implementing, distributing and using this utility? Consider political, economic and environmental factors.

Because your group will be the “expert” for your utility, you must prepare a crib sheet for your classmates to use when they analyze your utility in the field. Imagine the type of information you would want from an expert to analyze something you know very little about. Consider including the following information on the crib sheet:
- Brief history of the utility
- Possible locations for the utility; evidence of its presence
- Benefits of this utility’s presence
- Social costs associated with this utility’s presence

Homework:
- Continue with a log of each time you use of the utility you are researching. Add a second utility to your log and keep track of it as well.
- Take the previous night’s journal entry and rewrite it, commenting on the negative aspects of not having contemporary utilities available for each of the situations mentioned in the description of the typical weekday.

Day Three:
Continue researching and preparing class presentation and crib sheet.

Homework:
- Finish preparing your presentation for tomorrow.
- Continue with a log of each time you use utilities. Add all other six utilities to your log. Keep track of every time you use them over the next 24 hours.
- Take the previous night’s journal entry and rewrite it, commenting on the positive aspects of not having contemporary utilities available for each of the situations mentioned in the description of the typical weekday.

Day Four:
Conduct in-class presentations and follow-up questions
- Students should provide their “crib sheet” for the other members of the class

Homework:
- Students must study their crib sheets and prepare for tomorrow’s on-site test by choosing a particular outdoor location near their home and trying to determine the following:
  - Location of utilities
  - Sites of origin and deposit for the utilities
  - Ownership of utilities
purposes of this first plan was to prepare students for their
changes needed for the next century. One of the underlying
19th century urban growth and prioritize the infrastructure
writing assignment that asked students to reflect upon late
evaluation and assessment of outcomes consisted of a
became involved in the delivery of this material. Student
permitted the recruitment of two additional teachers to
presentation and a self study exercise. Circumstances
lesson plan was implemented as a combination of classroom
two history classes at Tampa Preparatory School. The first
outlined above were introduced by the teacher to students in
improvements in urban utilities, as well as evaluation of their
responses to the unit's three "essential" questions, posed both
at the beginning and the end of the five-day unit: 1) Do
utilities bring us closer together or drive us further apart? 2) What are the "social costs" of our utility infrastructure? 3) Have advancements in utilities transformed cities into "better" places to live? Qualitative evidence gathered from the responses to these three questions suggested that, while students had a greater appreciation of the function and placement of urban utilities, they generally remained quite positive about the environmental, economic, political and social costs that utilities have incurred on American cities.

CONCLUSIONS

As it turned out, the combination of the choice of utilities as a topic, the mutual interests of the teacher and faculty member, as well as the teacher’s previous experiences proved to be ideal match. Lesson plans prepared during the period of involvement at the University were successfully delivered and integrated at the teacher’s school. Because of the unique background of the teacher, this experience has been an opportunity to introduce technology in the context of liberal arts coursework (as opposed to math and science courses), thus providing another avenue for significant involvement for engineering at the high school level.

REFERENCES


IMPLEMENTATION OF LESSON PLANS

During the spring semester of 2003, the lesson plans outlined above were introduced by the teacher to students in two history classes at Tampa Preparatory School. The first lesson plan was implemented as a combination of classroom presentation and a self study exercise. Circumstances permitted the recruitment of two additional teachers to become involved in the delivery of this material. Student evaluation and assessment of outcomes consisted of a writing assignment that asked students to reflect upon late 19th century urban growth and prioritize the infrastructure improvements needed for the next century. One of the underlying purposes of this first plan was to prepare students for their

Day Five:

Students will be taken to an undisclosed location in the surrounding area. They will have 45 minutes to conduct a 360° survey of this space and fill out a worksheet—quietly and on their own—answering the following questions:

- What utilities do you see?
- What utilities do you not see? Why are they “invisible”?
- Trace these utilities to their source.
- Trace these utilities to their deposit sites.
- Who provides the services for these utilities?
- Are these utilities public or private?
- What are the positive and negative social costs of these utilities to the people at this location?

Homework:

- Imagine you have just read a multi-part series growth in your local newspaper detailing the findings of an extensive study of utilities and urban growth. Use this information, as well as the three journal entries you wrote this week, and write an editorial in the first-person for a newspaper addressing the following three questions.
  - Do utilities bring us closer together or drive us further apart?
  - Have advances in utilities transformed cities into “better” places to live?
  - Are you willing to pay the social, political, environmental, and economic costs for the utilities you use?
- Your editorial must conform to the following guidelines:
  - You must back-up your ideas with specific evidence
  - It must be a minimum of two pages
  - Provide a title for your editorial, knowing that it will be subtitled “The Price of Progress.”

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