

## **AC 2007-484: THE DEVELOPMENT OF ENERGY POLICIES BY UNDERGRADUATE ENGINEERING STUDENTS**

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# THE DEVELOPMENT OF ENERGY POLICIES BY UNDERGRADUATE ENGINEERING STUDENTS

## Abstract

This paper describes the incorporation of a project involving the development of energy policies by students in a senior-level technical elective course in Mechanical Engineering. As part of the course, students were engaged in a semester-long project that resulted in the development by each student of an energy policy that outlined the direction that they thought the United States should take over the next 25 years with regards to electricity generation.

The project consisted of several steps. First, each student had to choose one of nine possible electricity-generation techniques to research in depth. The students were then given two months to research the current state and projected improvements of their chosen technology, as well as the economics, environmental impact, and public perception of their technology. The students then were asked to prepare two reports on their research. The first report presented a detailed summary of their research, intended primarily for the instructor. The second report was a short summary of their findings, which were distributed to everyone in the class.

The next stage of the project lasted for two weeks. In this part, the students were to read the summaries provided by the other students, and then develop their own vision of the electricity generation infrastructure in the United States in the year 2030 and their plan on how to get to that point. The students then submitted their proposed plan, representing the development by each student of their own proposed energy policy for electricity generation.

Some of the benefits of this project are (1) the increased awareness on the part of the students on the roles that engineers can play in the development of public policy related to engineering issues, (2) improved writing skills so that these future engineers can better communicate with a non-technical audience, and (3) an opportunity to allow the students to consider contemporary issues and the societal context of engineering, as well as an exposure to some of the tools they need for life-long learning. This last benefit may aid programs with regards to ABET-accreditation. While conducting and grading the project, some ideas for improving the project were noted, and these are discussed as well.

## Introduction and Background

Engineers live and work in a society that often makes choices based on reasons other than technological merit. Yet the education of engineering students concentrates primarily in the scientific and design realms, and rightfully so as most engineers have to be very knowledgeable in these areas to perform their jobs well. But a disservice that this education provides is that many engineering students graduate without a good understanding of the non-technological issues that may impact their careers. Their education also often does not provide them with good skills for communicating their expertise to non-engineers. ABET, the Accreditation Board for Engineering and Technology, does try to have schools address these concerns by having them

include effective communication, an understanding of the economic, environmental, and societal context of their work, and a knowledge of contemporary issues into their curriculum.<sup>1</sup> However, many engineering programs find the incorporation of these into their curriculums challenging.

In an effort to address some of these curriculum issues, as well as to provide students with a new perspective on their possible future careers, a public policy formation project was created for students in the *MECHENG 435: Powerplant Theory and Design* course. This is a senior-level, technical elective course for Mechanical Engineering students at the University of Wisconsin-Milwaukee (UWM.) The course primarily considers the science and technology behind the generation of electricity in large powerplants. As energy, and the corresponding effects of energy usage on the environment, has become an important issue for the public in recent years, the author decided to create a project in which the students develop an electricity-generation energy policy for the next 25 years for the United States. As part of the project, the students were asked to perform detailed background research on one form of electricity generation, communicate their research results to the rest of the class, and then create their own individual proposed electricity generation policies for the United States.

The primary goals of this project are (1) to provide the students with an opportunity to learn about the creation of public policy and how they may impact the process, (2) to make the students more aware of contemporary issues facing the electricity-generation industry, (3) to improve the students' understanding of various electricity generation techniques, and (4) to improve the students' communication skills. All of these goals were met with this project. In working to achieve these goals, and the additional practice with writing, the students are being given the tools they need to potentially broaden their future career opportunities.<sup>2</sup>

In this paper, a description of the students involved in this project will be provided. In addition, a thorough description of the project, and a discussion of the positive impacts of the project will be given. Finally, some suggestions for improving the project, and for the implementation of this type of project in other forums will be given.

## **Student Profile and Course Background**

The Mechanical Engineering (ME) Department at UWM attracts a wide range of students. Some students are traditional, full-time students, others are part-time students, and some are students returning to college after working for several years. The average time for full-time ME students in the department to graduate is approximately 5 years. While some of the students have excellent abilities and would succeed at most schools, many of the students arrive at UWM with deficiencies in their math, science, or English skills. The students in the *MECHENG 435* course are primarily senior-level students, and have worked over the years to remove some of their deficiencies. But in many cases, the students may still lack some of the analysis skills that would be expected at many institutions. This profile is being presented to indicate that this public policy development project can be handled well by students with a wide range of skill levels.

The course in which this project was conducted, *MECHENG 435*, is a senior-level technical elective in the Mechanical Engineering Department. This course considers the science and

technology behind electricity generation, primarily as done in large powerplants. Depending on how the technical electives fit into their schedules, students usually take their technical electives during the last two years of their undergraduate education. The class meets twice a week, in 75-minute lectures. The course is offered every 3 semesters, and over the last eight years has seen class enrollment fluctuate between 7 and 25 students, with an average enrollment of 15. In the past several offerings of the class, the instructor assigned one short term paper asking the students to briefly research one electricity-generating technique and summarize the technology and the benefits and detriments to the technique. The students were also assigned a large project of designing the thermodynamic cycle for a combined cycle powerplant. As many of the students take a different technical elective with a similar cycle design project, the instructor decided to replace the two projects with a new public policy development project; this provided students with a different educational experience that would give them a different perspective on their future careers. In the Fall 2006 semester, when this new public policy project was implemented, 24 students completed the course.

### **Description of the Public Policy Project**

The project began with the instructor introducing some of the elements of public policy formation. These elements, at least for an energy-related policy, include the need for an assessment of the science and technology, a consideration of economic impacts, a need to assess the impact of the policies on the environment, as well as the political realities (through public perception) of the policy and its development. The need to bring together different constituencies and reach a consensus was discussed. In these lectures, the students were introduced to the elements of the creation of a public policy. In addition, throughout the semester, the instructor discussed how different topics covered in lecture might impact public policy development.

The instructor identified 9 different categories of electricity-generation techniques for consideration by the students. These are listed in Table 1. Some of the topics overlap somewhat, and so students were given latitude as to what they were to consider in depth. For example, a natural-gas fired combined cycle, or coal-gasification technology, could be seen as having both elements of the coal-fired Rankine Cycle and the Natural Gas-Fired technologies.

The students were then asked, in a randomly-selected order, to choose one of the techniques for their detailed consideration. With the number of students in the class, it was desired that each technology should have at least 2 students studying it in depth, and there was a limit of 4 students placed on each technique. The number of students who chose each technique is listed in Table 1. As can be seen, all but one technology, geothermal energy, had the desired minimum number of students focusing on it. The selection of the techniques was performed three weeks into the semester.

**Table 1:** Electricity generating technologies considered by the students, and the number of students who performed detailed research on the technique.

<b>Electricity Generation Technique</b>	<b>Number of Students</b>
Coal-Fired Rankine Cycle	2
Geothermal	1
Hydroelectric	2
Natural Gas-Fired Gas Turbines	2
Nuclear Fission / Nuclear Fusion	4
Solar Power	4
Trash-to-steam Rankine Cycle	2
Wave / Tidal / Oceanic	3
Wind Power	4

The bulk of the project then consisted of the students performing detailed research on their chosen technology, and preparing two reports. In their research, the students were to find information on and provide a summary of the following points:

- (1) a technical engineering description of the technology, including an assessment of the current state and usage of the technology;
- (2) a discussion of the environmental impacts of the technology;
- (3) a discussion of the economics of the technology, considering the capital and operating costs as well as any future potential incentives or taxes;
- (4) a discussion of the public perception and acceptance of the technology; and
- (5) a prediction of the state of the technology, along with its relative cost and environmental impact in the year 2030.

Therefore, the students were required to perform background research to get an understanding of the fundamentals behind their technology, as well as an understanding on how their technology fits into a societal and global context. Based on this information, the students were to prepare two reports. The first report, called the "Technique Evaluation," was to be a 10-page report thoroughly discussing the 5 points described above, and any additional relevant information that they uncovered. The second report, called the "Technique Summary," was to be a 1-2 page summary of the Technique Evaluation.

There were different purposes and target audiences for the two reports. The Evaluation was meant for the instructor of the class, and needed to demonstrate the depth of understanding that they achieved with their research. The details behind the technology were to be discussed in greater depth, as were the environmental, economic, and public perception factors. Also, future research directions expected for the technology were often included in these reports. The

purpose of the Summary was to put the Evaluation into a brief synopsis. The target audience for the Summary was to be considered the general public, but in practice would be their classmates. The students were not to expect a great deal of background knowledge from their audience, nor an ability to quickly learn about the technology in depth. Their summary was to contain only a one-paragraph description of the technology, written in a way that an intelligent, but uninformed, individual could understand the fundamentals behind the technique. They were then to concentrate their summary on the environmental, economic, and public perception information that they gathered, as that would be of most use to those developing public policies: the students in the class. They were also asked to provide "hard" information for the other students, rather than presenting vague general ideas. For example, the students were asked to find actual costs of a given technology, rather than stating "the technology is 'expensive.'" Both the Evaluation and the Summary were due two months after the selection of the technology.

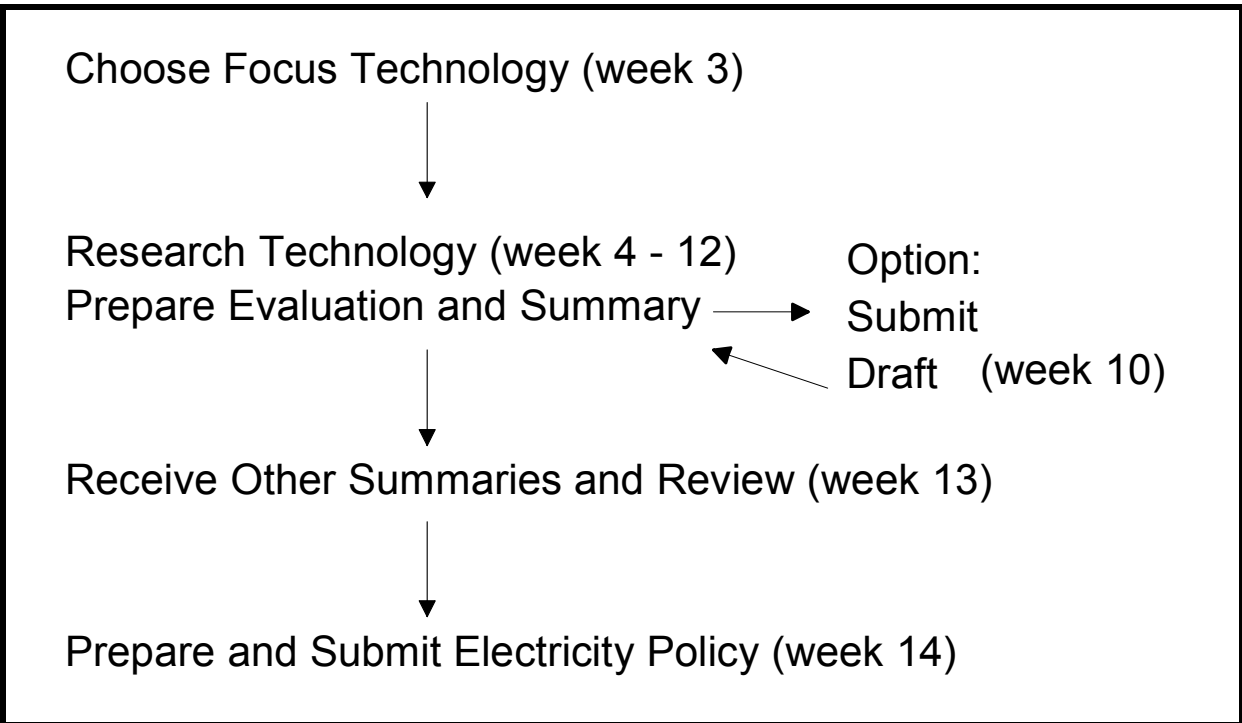
For the Technical Evaluations, the instructor did provide the students with an opportunity to turn in their evaluations for his review up to two weeks before the due date. Such a review of drafts has been found to be valuable.<sup>3,4</sup> In his review, the instructor would see if the students were missing any necessary information, and if they had obvious errors in their writing or report format. Eight students took advantage of this opportunity, and all improved their reports as a result of the review. In addition, some general problems (primarily in the formats of the reports) were noted by the instructor, and these were relayed to the rest of the class to aid them as well. However, most students who did not turn in a report for early review did not appear to benefit as much from these comments.

The instructor then prepared a hard copy of each Summary for each student in the class, and these packets were distributed at the following class. The students then had the last two weeks of the semester to read these summaries, and prepare a 2-3 page proposed Electricity-Generating Policy for the United States to follow for the next 25 years. These policies were to include what the student proposed for the landscape of electricity generation in the year 2030, how the United States should phase in new capacity, what should be reduced or phased out, and where to spend research money to develop improved technologies. As there was no single correct answer, the students were asked to justify their decisions considering the environmental, economic, and public perception factors described in the student Summaries. If information was not available in the student Summaries provided to the class, the students were not expected to have found this information independently. This was done to teach the students about the need for sufficient quality information when creating a public policy, and would help them learn what would be good for them to include in such Summaries in the future.

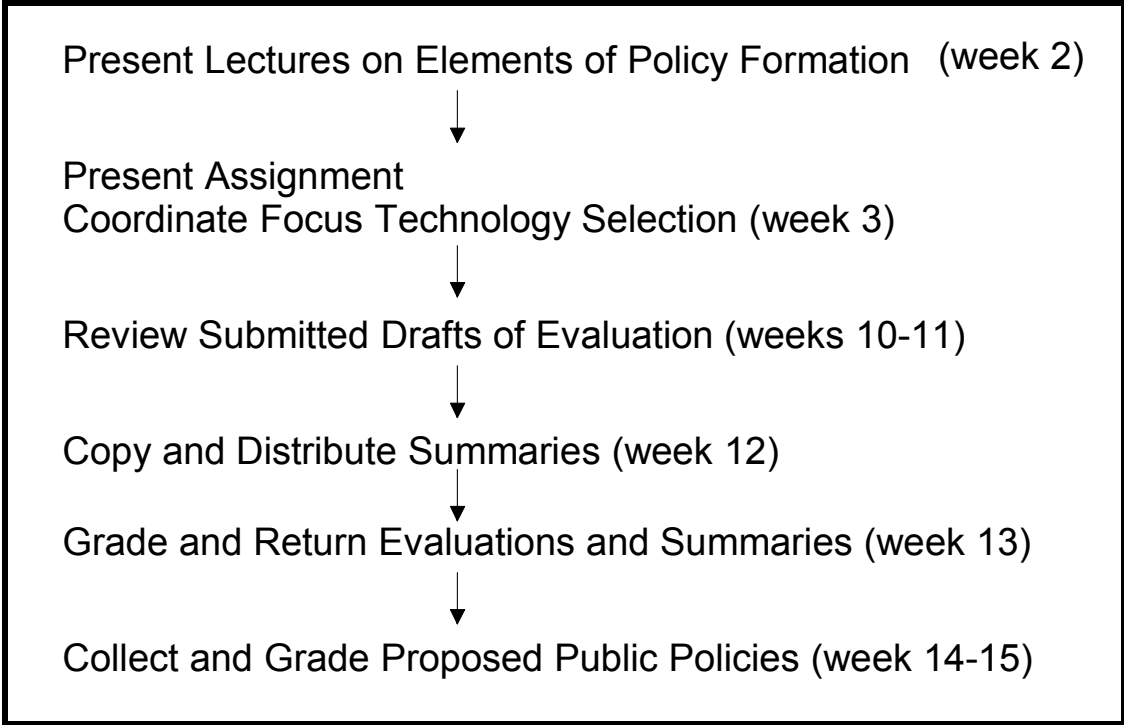
Figure 1 provides a diagram showing the tasks that were undertaken by the students in the project, and Figure 2 provides a diagram showing the instructor tasks for the project.

### **Observations on Policy Project Submissions**

While 24 different projects were completed by the students, and there was not one common fault present in each project, there were some trends that were observed by the instructor. Some of these trends were positive, and others were negative. The positive trends can be taken as



**Figure 1:** Summary of Tasks for Students in Electricity-Generation Policy Project.



**Figure 2:** Summary of Tasks for Instructor in Electricity-Generation Policy Project.

evidence of how this type of project can be successful, while the negative trends can be seen as areas where improvement is needed in the project format in the future. The negative trends can also be used as cautionary items for instructors in other institutions, although it must be remembered that some of the negatives may be a result of the typical student profile, or preparation, at UWM.

First, some of the positive observations are as follows.

- (1) Each student prepared a good Technology Evaluation and realistic Electricity-Generation Policy. This is not to say that there were not some problems with the Evaluations. For example, some of the evaluations tended to deviate from covering specifically electricity generation; this was particularly a problem with solar energy. In addition, the Policies were in some cases rather idealistic. But overall, the Evaluations and Policies were good.
- (2) Students tended to not overly favor their own focus technology in their public policies. A few students were biased towards the technology that they had personally researched, but most of the students seemed to go into the policy formation phase of the project with an open mind.
- (3) Most students successfully learned about the different technologies from their classmates, and used that information in the formation of their policies.
- (4) Most of the students did find hard information from authoritative sources, rather than relying on soft information with regards to environmental, economic, or public perception.
- (5) Some rather creative, but feasible, solutions to certain problems were suggested.

These positive observations greatly outweigh the following negative observations. But the negative observations are being included below to illustrate where improvement is needed, or where some unexpected occurrences may occur.

- (1) The format of the student Technical Evaluations was often poor. A common trend among nearly all the students was the lack of an introduction into their report, or a summary at the end of the report. As these are senior-level college students, this was of considerable concern.
- (2) Many students' writing styles also were not professional. Many of the Technical Evaluations, which should have been written in the style of a professional technical report, were written using informal or folksy language. However, on the positive side, after this was pointed out to the students in the grading of their Evaluations, the students wrote their Policies in a more professional manner.
- (3) Some students will come into this project with almost no knowledge of contemporary electricity-generation issues. For example, one student, whose focus was nuclear energy, was surprised by the number of concerns that exist in the public perception's of nuclear fission. Other students were confusing ozone hole depletion and global warming. While this is being listed as a negative observation, it can also be considered an opportunity for the students to learn from their work on this project.



(4) Some students do not know how to go about researching a topic, and may be drawn to unreliable sources. Students need to be taught how to go about researching a topic and finding reliable sources.

(5) Many of the students concentrated on the positive aspects of their focus technology in their Technology Evaluations, rather than giving equal consideration to the negative aspects. Interestingly, as noted in the second positive observation, this did not carry over much into their final policies.

(6) Students need more education on how to establish a hierarchy of effects from different activities. For example, one of the students researching hydroelectric power found a study that considered the impact on the greenhouse gases emitted by decaying plant life that is underwater after a dam is built. The result of this was that a number of students, in creating their Policies, gave that impact a similar weight in terms of greenhouse gas emissions as the CO<sub>2</sub> emitted by coal-fired powerplants. If the students would know more about assessing impacts, that sort of interpretation is unlikely.

(7) Most of the public policies focused on the landscape of electricity generation in the year 2030, and some did propose where to direct research money. Unfortunately, most did not go into detail on how to phase in or phase out technologies.

To summarize these observations, the reports were generally well done. Improvements are needed in the writing style and report format, but as the styles improved for the Policies, it is surmised that the students primarily need to be reminded about proper report writing style. The students were able to provide meaningful information to, and learn from, each other. The students do need more education on how to assess information, and some need more education on how to research topics.

### **Benefits of the Public Policy Project**

From an engineering education viewpoint, there are a number of benefits that are achieved with this project. First, students are given a project experience that goes beyond the standard design or laboratory projects. Decisions in their future will be made for reasons other than only technological merit. This project gives students the opportunity to learn more about economic, environmental, and public perception factors that may impact their careers in the future.

Second, students get additional experience to improve their written communication skills. In this project, they have to write two different types of reports. One report is a technical report, targeted towards an engineering audience, while the second report is a brief summary, targeted towards a wider, mass audience. Both of these writing styles are important, and the style of writing directed towards a larger audience is not one frequently practiced in engineering education. A benefit of the requirement for turning in different reports at different points in the semester, as well as the opportunity to have the instructor review their report ahead of its due date, is that the students can use the feedback received to improve their writing in the subsequent

reports. The students can also learn from their classmates' summaries how their writing may be received by others. If the students find that their classmates are not providing them with sufficient information, they may learn what to put into their own reports to most benefit others.

Third, students are exposed to a different way in which they can use their engineering education in their future careers. The students see that they can use their skills to potentially influence or create public policy.

Fourth, this type of project provides programs with an opportunity to help satisfy some of the ABET criteria for accreditation that are often difficult to fit into the normal engineering program. This project gives students the ability to learn about the global, economic, environmental, and societal context of engineering, a knowledge of contemporary issues, and practice with their communication skills.

Fifth, the students learn more about the technology involved the different electricity-generation techniques. Writing about the topic tends to cause students to learn the material more thoroughly than they achieve by sitting in lecture or reading a book.<sup>2</sup>

Sixth, with some modifications to its implementation, the project can give students more experience conducting information research. The students can also learn about and practice interpreting and assessing information.

### **Areas to Improve the Public Policy Project**

After assigning and conducting this project, the author has noted several ways to potentially improve the project. First, the instructor will consider giving the students either a list of questions to be answered by their research, or provide a table of important data to be filled in by the students. In these ways, the students would have specific questions to answer with their research. While this may reduce some of the freedom that the students had in their projects, it will help target their research on the most important issues.

Second, the report format and writing style needs to be emphasized repeatedly. Not only will this result in better reports, the emphasis will help the students with their communication skills. It should be noted that the feedback did noticeably improve the writing for the Policies. This suggests that the students have some knowledge on how to write the reports, but that they may fall into bad habits if not reminded about the correct procedures. Early emphasis should help alleviate this.

Third, provide additional lecture content on some past examples of how a large infrastructure was changed over the years. The biggest deficiency in most of the Policy documents was a lack of a conversion strategy for the electricity-generation infrastructure. The students tended to provide the desired final infrastructure without considering how to reach their plan.

Fourth, discuss in class how to evaluate the quality of a piece of information, and how to assess the impacts or consequences of an action or event. Students also could use some assistance in

learning how to find quality information. It has been found that students who do not regularly access a library or conduct research will often have problems with these issues.<sup>5</sup> For this it might be helpful to bring in a librarian to provide some guidance at the start of the project.

One item that should be noted is the appropriate size of the class for this type of project. A key element of this project was the sharing of information between the students through the Technology Summaries. In this project, the students received 23 summaries from their classmates. Considering the time frame in which the students had to work to formulate their policies, that was probably at the upper limit of what the students could use. Trying this project in this exact format in a class of 50 would likely overwhelm the students. On the other hand, considering the number of technologies involved, one would not want the students to have fewer than 2 summaries for each technology. This indicates that one needs to modify the project for the size of the class. A smaller class may need to consider fewer technology options. A larger class may need to work on this project in teams, with each team being responsible for a Technology Evaluation and Summary.

This type of project should also work well at different levels in the curriculum. When assigning this type of project, the expectations on the students need to be made according to their level of education. This type of project can even be of use in the freshman year, as it can give engineering students a different perspective of engineering at the start of their education. That enhanced perspective may then carry over through the rest of their studies.

## **Student Impact**

In order to learn how this project impacted the students, the instructor conducted an eight question survey. The students were asked to what degree they agreed with the statement provided, with 5 corresponding to “Strongly Agree”, 3 to “Neutral” and 1 to “Strongly Disagree.” Twenty-one of the 24 students who worked on the project completed the survey. The statements, and average score, are provided in Table 2.

As can be seen from the first statement, the students averaged out to being neutral on their understanding of issues before the project, and only 38% agreed to some degree with the statement. After completing the project, all the survey respondents agreed with Statement 2 that the project made them more knowledgeable on the issues and techniques, with the majority strongly agreeing with the statement.

Looking at individual aspects of the project, all respondents agreed with the statement that the project improved their knowledge of the individual technology that they studied in depth (Statement 6,) with again, most students strongly agreeing with the statement. As seen in Statement 3, 86% of the students agreed that they were more aware of environmental issues after finishing the project, with an average score of 4.38. However, the impact of the project on their awareness of public perception and economic issues only received average scores of 3.90. In Statements 4 and 5, 81% agreed with the statement on economic issues, while only 62% agreed

**Table 2:** Statements and Average Scores from Student Survey on the Energy Policy Project.

<b>Statement</b>	<b>Average Score</b>	<b>Number who “Agree” or “Strongly Agree”</b>
1. I was very aware of issues with electricity generation before beginning this project.	3.05	8
2. My knowledge of the issues and electricity generation techniques improved with this project.	4.81	21
3. The project made me more aware of environmental issues.	4.38	18
4. The project made me more aware of the importance of public perception of engineering projects.	3.90	13
5. The project made me more aware of the impact of economics on engineering projects.	3.90	17
6. The project increased my knowledge of the individual technology I studied in depth.	4.81	21
7. The project made me more likely to try to be involved in public policy formation or decisions in the future.	3.33	12
8. My thoughts on how we should generate electricity in the future changed while/after working on this project.	4.10	17

with the statement on public perception. Considering these two questions, and the content of the students’ projects, it is likely that the result on public perception was a result of the students placing less emphasis on that aspect of the project in their research. The economics result is probably more an indication that the students feeling more comfortable with the economics of the different techniques before conducting the project, as that is covered more during the course lectures.

Statement 8 indicates success from the project in causing the students to now give additional thought as to how electricity is generated in the United States, as 81% of the students agreed that their thoughts on how electricity should be generated has changed. This is likely a reflection of both the students’ increased knowledge of different techniques and what they learned about the environmental effects, economics, and public perception of each technique.

From the viewpoint of encouraging engineering students to become more involved with policy formation in their careers, the results from Statement 7 are the most apropos. The average score for how much the students are likely to try to be involved in public policy decisions in the future comes in slightly above neutral, and only 57% of the students agreed with the statement; none of those “Strongly Agreed.” This result is not surprising, as most of these students are studying engineering, and not public policy. Therefore, the students are not likely to be inclined towards policy formation at this point in their lives. Considering that, having more than half the respondents say that they are at least somewhat more interested in being involved in policy formation indicates some significant impact from this project.

From the student survey, it can be seen that the students' knowledge of electricity generation issues and techniques increased greatly with this project. Their awareness of environmental issues, economics, and public perception increased with this project, with the largest increase with environmental issues. Finally, there is some indication that many of the students enjoyed the project enough to be more interested with the formation of public policy in the future.

## **Summary and Conclusions**

A complete description of a public policy creation project involving electricity generation has been presented. The primary goals of the project were to help the students learn more about the creation of public policy, increase their knowledge of contemporary issues involving electricity generation, improve their understanding of electricity generation techniques, and to improve their written communication skills. All of these goals were met with this project.

The benefits of this type of project include (1) providing the students a different type of engineering project which provides both a different way of learning the subject material and a view of a different type of career path they may choose to follow, (2) giving the students feedback on their writing, and the opportunity to practice writing different types of reports, and (3) providing a method of satisfying some of the more challenging ABET criteria for accreditation. Several ways to improve the project, and to modify it to different class sizes, were also provided. A student survey conducted upon the completion of the project provided insight into how the students felt the project affected them.

In conclusion, this project demonstrates a possible method of introducing engineering public policy into a standard engineering curriculum. The project can be used as is, or the topic can be modified to address other pressing public policy concerns involving engineering. The project format should work well, with simple modifications, for any class size. Finally, the project format can be used at any stage in the curriculum, provided that expectations are set at the appropriate level and instruction on research and evaluation practices are targeted to the correct audience.

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