Public Policy Analysis for Engineers

Prof. Deborah Diane Stine, Carnegie Mellon University

Dr. Deborah Stine is Professor of the Practice for the Engineering and Public Policy Department and the Associate Director for Policy Outreach for the Scott Institute for Energy Innovation at Carnegie Mellon University (CMU). She was Executive Director of the President's Council of Advisors on Science and Technology (PCAST) at the White House from 2009-2012. From 2007-2009, she was a science and technology policy specialist with the Congressional Research Service, where she wrote reports and advised members of Congress on science and technology policy issues.

From 1989-2007, she was at the National Academies – the National Academy of Sciences, National Academy of Engineering, Institute of Medicine – where she was associate director of the Committee on Science, Engineering, and Public Policy; director of the National Academies Christine Mirzayan Science and Technology Policy Fellowship Program; and director of the Office of Special Projects. While at the National Academies, she was study director of the landmark National Academies report entitled Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future which proposed the creation of the now established Advanced Research Projects Agency – Energy (ARPA-E). For this work, she received the Presidents Award– the highest staff award offered at the National Academies.

Prior to coming to the Academies, she was a mathematician for the Air Force, an air-pollution engineer for the state of Texas, and an air-issues manager for the Chemical Manufacturers Association. She holds a BS in mechanical and environmental engineering from the University of California, Irvine, an MBA from what is now Texas A&M at Corpus Christi, and a PhD in public administration with a focus on science and technology policy analysis from American University.

Dr. Deanna H. Matthews, Carnegie Mellon University

Dr. Deanna H. Matthews is Associate Department Head for Undergraduate Affairs and Assistant Teaching Professor in Engineering and Public Policy, as well as Education Director and researcher in the Green Design Institute at Carnegie Mellon University. In her role in Engineering and Public Policy, Dr. Matthews oversees the undergraduate programs in EPP. In the Green Design Institute, her research centers on the development and deployment of the Economic Input-Output Life Cycle Assessment tool. As Education Director, she oversees education and outreach initiatives for the Green Design Institute. She is the coordinator and instructor of outreach programs to K-12 students and teachers in school settings and informal educational events. She received her B.S.E. in Civil Engineering from Duke University (1994) and her M.S. (1995) and Ph.D. (2001) in Civil and Environmental Engineering from Carnegie Mellon University.

Ms. Nichole Hanus, Carnegie Mellon University

Nichole Hanus is currently pursuing a PhD in the Engineering and Public Policy department at Carnegie Mellon University. She holds a B.S. in Mechanical Engineering with a focus in energy systems from the University of Dayton. Currently, her research combines behavioral decisions sciences and social network analysis methods to identify the catalysts to energy efficient designs and practices.

©American Society for Engineering Education, 2016

Public Policy Analysis for Engineers

Introduction

Public policy issues are important to every field of engineering. Yet, most engineering students know little about issues facing their field nor how to analyze potential public policy options in a neutral fashion. Instead of an entire course focused on the topic, faculty can incorporate an understanding of public policy and neutral policy analysis into existing courses.

To respond to this need, Carnegie Mellon University has developed a free online "Public Policy Analysis for Engineers" (http://oli.cmu.edu/courses/free-open/policy101/) module where engineering students learn about the interrelationship of engineering and public policy, how to conduct neutral policy analysis, and then apply that knowledge in engineering-focused case studies to practice the skills they have learned. The module takes a flipped classroom/active learning approach by using short videos to educate students, activities to practice the skills taught, and incorporates real-world examples such as hydraulic fracturing, drones, and 3D printing.

The public policy analysis for engineers module was initially a worksheet developed to help walk engineering students through the eight steps of University of California-Berkeley Professor Emeritus Eugene Bardach's "A Practical Guide for Policy Analysis: The Eightfold Path to More Effective Problem Solving."[1] First published in 2000, and now in its 5th edition, "A Practical Guide" is a short, easy-to-read and understand guide based on the work of well-known public policy intellectual leaders. The eight steps include:

1. Define the Problem
2. Assemble Some Evidence
3. Construct the Alternatives
4. Select the Criteria
5. Project the Outcomes
6. Confront the Trade-offs
7. Decide
8. Tell Your Story

In teaching engineering students, however, we found that a more programmatic approach based on this text was necessary. As opposed to students Bardach taught in developing the guide in Berkeley's public policy school, many undergraduate engineering students had limited education in public policy as part of their pre-collegiate education, and for the international students that we most frequently encountered in master or PhD programs, some of the core principles were not the same in their home countries' public policy system.

The on-line module and related videos are freely accessible so that faculty at any institution can incorporate them as they wish into their courses. Universities that use blackboard may be able to incorporate them directly into their course website.
The module is designed to satisfy ABET criteria related to public policy and society, can be used in a class focused on the interface of engineering and public policy, or over one or more sessions

in a class focused on another topic. Instructors can easily incorporate topics relevant to their course in the framework of the on-line module.

There are also case studies where students can apply the principles learned to a variety of engineering-related situations. Currently, only 3D printing is included in the module, but we have written material for additional technologies that will be incorporated in the Spring/Summer 2016: energy efficiency, energy storage cybersecurity, electricity generation, sustainable vehicles, desalination, energy access, organic compounds, and edible electronics.

In this paper, we will describe the module and pedagogy, share our experience with using the module in courses over a two-year period, the data that shows its impact on student outcomes, and suggest ways for others to incorporate the module into their courses.

Context and Goals

The online module is designed to satisfy ABET criteria 3c and 3h, which require that engineering students develop:

- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.[2]

Some of the ABET criteria are proposed for revision in 2016-2017, but the following draft definition of "Engineering Design" shows ABET continues the connection between engineering and public policy:

> Engineering Design – Engineering design is the process of devising a system, component, or process to meet desired needs, specifications, codes, and standards within constraints such as health and safety, cost, ethics, policy, sustainability, constructability, and manufacturability. It is an iterative, creative, decision-making process in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally into solutions.[3]

The College of Engineering at Carnegie Mellon University funded the project – both the online module and related videos -- through its internal "Innovations in Engineering Education" program.

Public Policy Analysis for Engineers Online Module

The Public Policy Analysis for Engineers online module has three units: Policy Analysis Overview, How is Public Policy Analysis Conducted?, and Public Policy Analysis Cases. The learning objectives for each are provided below.

Unit 1: Policy Analysis Overview
This unit has the following learning objectives:

- Define public policy and public policy analysis
- Describe how policymakers, stakeholders, and policy analysts influence public policy decisions
- Describe why a well-informed and neutral analysis of existing and potential public policies is important for optimal societal outcomes

Unit 2: How is Public Policy Analysis Conducted?
This unit has the following learning objectives:

- Develop a policy-neutral question appropriate for policy analysis that does not include the proposed solution or presume there is a problem
- Assess the potential accuracy and completeness of available policy-relevant information, including identifying the current policy
- Identify, evaluate and compare the positive and negative outcomes of potential policy solutions (including the status quo) according to the criteria you have selected (typically the 4 E's: effectiveness, efficiency, equity, and ease of political acceptability)
- Predict the various parties interested in taking or opposing action on this policy and their policy position
- Clarify complex policy issues for policymakers in a clear and concise narrative that recognizes obstacles to the recommended policy

Unit 3: Engineering-Based Case Studies
In addition to the objectives in Unit 2, this unit has the following learning objective:

- Apply public policy analysis principles and methods to current technologies.

We provide a description of each of these Units below, including some of the materials and screenshots from the tool. Within the on-line module, an example case of a "Soccket" ball[4] is used to guide students through the different activities. We use that example case here to introduce the different elements of the module as well.

Unit 1: Policy Analysis Overview

Given that most engineers do not study public policy analysis, we began the module by answering the question: "What is Public Policy Analysis?" In this unit, we use illustrations to focus on the following concepts:

- The purpose of public policy analysis is to help policymakers make choices to questions such as these based on a thoughtful and neutral analysis of the situation based on the best information available while taking into account uncertainties.

- The analysis includes breaking down a problem into actionable components, identifying potential solutions, analyzing those potential solutions and comparing them based on a set of pre-determined criteria, and then identifying the optimal solution for a client based on the evidence available.

- Public policy analysis is more of an "art" with no "engineering manual" to tell you the exact options to analyze or calculations that lead to only one answer. This is because it is often influenced by the context of the situation and constantly changing human behavior.

- Public policy analysis is looking toward the future as opposed to program evaluation, which looks at past performance**.** Since the future is unpredictable (as is human behavior), there is always uncertainty and risk. As a result, risk and uncertainties always need to be acknowledged in the analysis, qualitatively or quantitatively, and it must be written very carefully to make this situation clear. There is no one "right" answer to a public policy situation, only degrees of likelihood of success for a specific client based on the available data at a given point in time.

Why Should Engineers Learn about Public Policy Analysis?

Next, we wanted to encourage students to be interested in the topic by explaining why engineers should learn about public policy analysis. By understanding public policy issues and how they are analyzed, we tell students that engineers can:

- recognize potential policy issues related to an engineering-related activity before it occurs,
- identify a potential engineering solution to avoid the public policy challenge in the first place -- particularly important for emerging technologies,
- improve the ability of themselves or their organization to participate in the public policy process by understanding the key institutions and influencers related to that policy,
- and provide advice to policymakers about engineering and technology-related issues.

As an illustration, we focus on the 14 Grand Challenges identified by the U.S. National Academy of Engineering.[5] As shown in Table 1, each of these grand challenges will result in important policy questions. Those listed in the table are just illustrations of what are undoubtedly many policy questions that need to be addressed. Table 1 also provides illustrations of policy analysis that address these questions.

Table 1: National Academy of Engineering Grand Challenges and Illustrative Policy Questions and Analysis

Challenge	Illustrative Policy Question	Illustrative Policy Analysis
Solar Energy	Should policies to encourage reducing the cost of solar energy occur at the state level instead of the national level, given that this energy source is likely to be more economic in some parts of the country, such as the southwestern United States, than others?	Nelson, David. "The Role of Government Policy in the Development of Solar Photovoltaic Power," Climate Policy Initiative, May 31, 2011.[6]
Fusion Energy	Does the nation need an "Apollo program" (as proposed by one advocacy group) that would demonstrate fusion energy?	Holland, Andrew and N. Cunningham, "Fusion Power: A Ten-Year Plan for American Energy Security," 2014, American Security Project.[7]
Carbon Sequestration	What enabling policy and regulatory framework should be taken to advance carbon capture, utilization, and sequestration in California to meet the state's greenhouse gas goals?	Burton, Elizabeth, N. Mateer, and J. Beyer, "California's Policy Approach to Develop Carbon Capture, Utilization and Sequestration as a Mitigation Technology," Energy Procedia, 2013.[8]
Global Nitrogen Cycle	What economic incentives are needed to encourage better management of the global nitrogen cycle?	Erisman J. et al., "The European nitrogen problem in global perspective," Chapter 2 in The European Nitrogen Assessment, 2011, Cambridge University Press.[9]
Health Informatics	What policies can be undertaken to encourage the interoperability of health information record so data can be shared to enhance the quality of patient care?	President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Health Information Technology to Improve Healthcare for Americans: The Path Forward," 2010.[10]
Engineer Better Medicine	What policies could be put in place to advance personalized medicine taking into account issues such as interoperability, inconsistent coding and language standards, problems in data sharing, weak feedback loops, privacy concerns, and ineffective reimbursement policies?	West, Darrell, "Enabling Personalized Medicine through Health Information Technology Darrell West," Brookings Institution, January 28, 2011.[11]

Challenge	Illustrative Policy Question	Illustrative Policy Analysis
Brain	Should neuroethics policies or a neuroethics research program be put into place by policymakers that address concerns about the ethical, legal, and social implications of reverse engineering the brain?	Garnett A, Whiteley L, Piwowar H, Rasmussen E, Illes J. Neuroethics and fMRI: Mapping a Fledgling Relationship. Sirigu A, ed. *PLoS ONE*. 2011;6(4):e18537. doi:10.1371/journal.pone.0018537.
Nuclear Threat	What should be the U.S. nuclear weapons policy?	Committee on International Security and Arms Control, National Academy of Sciences, "The Future of U.S. Nuclear Weapons Policy," 1997.[12]
Cyberspace Threat	What policies should be undertaken to reduce the cybersecurity threat?	Clark, D., T. Berson, and H.S. Lin, "At the Nexus of Cybersecurity and Public Policy: Some Basic Concepts and Issues" Committee on Developing a Cybersecurity Primer; Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences; National Research Council.[13]
Virtual Reality	Should Veteran's Hospitals put into place a low-cost virtual reality program to help soldiers with post-traumatic syndrome?	Meeker, Daniella, J. Cerully, M. Johnson, N. Iyer, J. Kurz and D. Scharf. "SimCoach Evaluation: A Virtual Human Intervention to Encourage Service-Member Help-Seeking for Posttraumatic Stress Disorder and Depression." Santa Monica, CA: RAND Corporation, 2015.[14]
Personalized Learning	What policies can state and local policymakers take to enable personalized learning?	Chuong, Carolyn and S. Mead, "A Policy Playbook for Personalized Learning: Ideas for State and Local Policymakers," Bellwether Education Partners, June 2014.[15]
Discovery	What is the appropriate balance of funding between engineering tools for research and funding the research itself?	National Academies, Committee on Science, Engineering, and Public Policy, "Advanced Research Instrumentation and Facilities," 2006.[16]

What Perspective Should Engineers Take to Analyzing Public Policy Challenges?

Engineers also often need to take a systems approach to analyzing public policy challenges. As described by E.S. Quade, a systems approach is "a way to investigate how best to aid a decision maker faced with complex problems of choice under uncertainty, a practical philosophy for carrying out decision-oriented interdisciplinary research, a perspective on the proper use of available tools."[17]

So that students could understand this concept in the online module, we developed a case study on the "Soccket" ball – a product developed by college students, who did not necessarily have a full understanding of the system within which this product would operate, and as a result did not achieve the societal goal that was the focus of their design. Figure 1 provides this "learn by doing" case study as shown in the module.

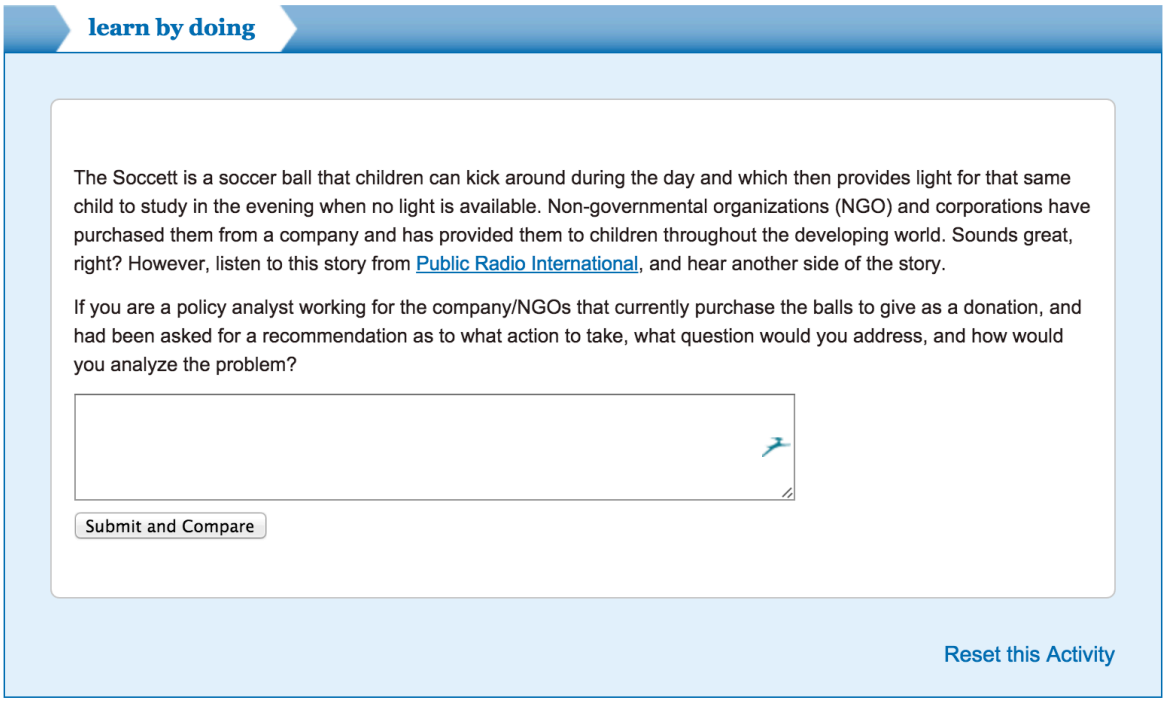

Figure 1: "Learn by Doing" Case Study: Soccket Ball

The Public Radio International story mentioned in the call study explains that there are a number of challenges to implementation of the Soccket ball concept in the societal context in which the innovation was used. First, the balls sometimes broke after only a few days and so did not provide the light the students needed and disappointed the students regarding technology. Second, parents said that for the cost of the ball, their home could have been wired so that electricity was available on a regular basis, not just after the child kicked the ball resulting in limited light. Students respond to the question in Figure 1 and then are provided the guidance in Figure 2 as to how they should think about the problem after they hit "submit and compare":

As mentioned above, there is no one answer to respond to a policy challenge. In trying to identify the question to address, you need to first think...Is it to

1. Fix or replace the Soccett balls?
2. Provide the least expensive form of energy so students can study at night?
3. Provide a clean source of energy so students can study at night?
4. Publicity as to what a kind company or NGO you are?

If it is to provide a form of energy so that students can study at night, what are some options for responding? If so, then your second step is to reframe the question so that policymakers get the analysis they need to make the optimal decision. This question might be:

✔ *What actions, if any, should be taken to provide students in developing countries without light at nighttime with lighting?*

An alternative would be to answer the narrower question focused just on the Soccett balls, but that might not be the overall goal of your policymaker --- thought it might be for the company that sells the balls.

Your next step would be to conduct research to try and answer this question. This might involve gathering ideas from those in that population influenced as well as their government leadership. Overall, in developing policy options, you want to think about how effective the policy will be in achieving your policymaker's goals, what policies are most like to be efficient in "getting the most bang for the buck," who are the winners and losers, and how easy it will be to get the acceptance of the key stakeholders and other policymakers.

Figure 2: Feedback to Students After Responding to Soccket Case Study

Unit 2: How is Policy Analysis Conducted

The next unit goes over the eight steps in the Bardach guide. Some of these steps were modified slightly to enhance student understanding.

Problem Question vs. Problem Statement: Step One in the Bardach guide[18] is "Define the Problem." So, for example, you might say "Too many families are homeless." He also points out that you should not imply the solution in the problem statement, by saying, for example: "There is too little shelter for homeless families."

Yet there is another challenge that face engineers as they encounter situations that may not yet have occurred or with limited data, so the situation that needs to be evaluated first is whether or

not there is a problem, and then if there is one, whether or not current policies (the "status quo") are sufficient to address the problem.

Other issues that need to be addressed in the question are the geographic region (as the answer in one area might differ from another) and what entity might take action (as jurisdiction plays a key role in what actions can be taken.) Using the Bardach sample problem statement as an example, the module teaches students to change it to something like the following:

> "What actions, if any, should be taken by the Pittsburgh Mayor's office to address concerns that too many families are homeless in Pittsburgh?"

or in more of an engineering context

> "What actions, if any, should be taken by the Occupational Safety and Health Administration to address concerns that 3D printing is producing ultrafine particulate matter in retail settings in the United States?"

And then in their analysis to understand the degree to which there is a problem (if any) and the status quo – the existing policies that may be relevant in this situation. Figure 3 provides an illustration of how this is taught in the module.

EXAMPLE

What actions, *if any* should be taken by *Alberta's Minister of Environment and Sustainable Resource Development* to *encourage companies* to reduce their *greenhouse* gas emissions from *oil sands* in *Canada*?

This is a good example as it is policy neutral and clearly identifies the policymaker who has the authority, jurisdiction, and the energy source in their region sufficient to take the action if that is the result of the anaylsis, and specifies the type of environmental concern and geographical area. Provided below are annotations of some of the key elements of a good policy statement question:

"if any" –> no additional action is presumed. In Alberta, for example, they already have a carbon tax so the question is, is that tax sufficient? In other provinces, there is no tax on companies, but there is on mobile sources.

"Alberta's Minister" --> individual (or organization) taking action

"encourage" –> the action may be voluntary or a requirement

"companies" –> there is specificity as to the sources involved (for example, mobile sources are not included)

"greenhouse," "oil sands," Canada" –> all provide additional specificity as to which pollutants from what source in what location

Figure 3: Example of Policy Analysis Question Design

Criteria for identifying, evaluating, and comparing policy solutions

4E Criteria vs. Many Criteria: The Bardach guide identifies many criteria that can be used to evaluate public policy options. From an engineering standpoint, it is useful to focus on what we call the 4E's: effectiveness (the degree to which a societal goal is reached), efficiency (the cost relative to the degree of societal benefit), equity (who are the winners and losers), and ease of political acceptability (often called responsiveness, which is the degree to which stakeholders will oppose or support the option). This is then linked to methods frequently taught to engineers such as benefit-cost analysis, risk analysis, life cycle assessment, and one not often taught, prince[19] analysis, a political analysis that assesses the position, power, and salience of the key stakeholders relative to a particular policy option.

In operationalizing these 4E criteria, it is important to take the systems approach described earlier. The module uses a simple parking example – students and staff want more parking on campus and are protesting the lack of it to the campus President's office. One option proposed is satellite parking. As illustrated below, there are the obvious questions of effectiveness and efficiency, but it is important to also consider issues of equity and ease of political acceptability.

- **Effectiveness:** How likely is it that satellite parking will be sufficient to satisfy the demand for affordable parking?
- **Efficiency:** What will be the cost of satellite parking relative to the additional parking gained?
- **Equity:** How fair and equitable is satellite parking to all the stakeholders?
- **Ease of Political Acceptability:** Are faculty, staff, and students likely to support, oppose, or be neutral about satellite parking?

For example, perhaps parking is intentionally expensive and limited in order to reduce the air pollution emissions from vehicles on campus involving equity issues. So adding more parking will create winners for those who want affordable parking, but it will possibly create losers as well. And when looking at ease of political acceptability, you may make those protesting the change happy, but will making this change create another set of concerns with local neighbors.

- **Effectiveness:** Maintaining existing policies will lead some faculty, students, and staff to go to other institutions instead.
- **Efficiency:** A new parking policy that provides an option for lower-cost satellite parking with a shuttle will benefit the most parkers at the lowest cost.
- **Equity:** A higher or lower parking fee (e.g., tax policy) will primarily affect low-income students who do not live close to the university to obtain lower housing costs, but who have no mass transit options. Also affected will be families with small children who may find it difficult to go to daycare facilities or meet daycare center time limits if mass transit is used. One question is whether or not air pollution emissions or traffic-related fatalities will increase due to an increase in the number of people driving.
- **Ease of Political Acceptability:** The protesters might be pleased to get satellite parking as an option, but the neighbors who live on the pathway of the shuttle bus may not be happy as it increases traffic of large and noisy vehicles in their neighborhood -- will they now protest instead?

***Pro-Con Analysis of Policy Options Using 4E's*:** The simple parking example illustrates the importance of encouraging students to do a pro-con analysis. There is a tendency of all students to identify only the reasons their policy idea should occur, and not the reasons it may not be a good idea**.** This would be advocacy rather than analysis. So the module provides a table (Figure 4) for students to fill in that forces them to consider the pro and con for each of the 4E's for each policy option. Students then balance the pro's and con's to provide an overall assessment, and use symbols to portray their results. Particularly important is looking at their options relative to the status quo (existing) situation.

learn by doing

Project the Outcomes

Instructions: For each option, fill in a brief summary of your option, and a pro/con for each criteria. For example, the "pro" would describe why the option is likely to be effective, and a "negative" a reason why it is not likely to be as effective. In the last column, use these reasons to make your final assessment using the following symbols:

- Put in a "+" if you think the answer is more likely to be positive than negative
- Put in a "-" if you think the answer is more likely to be negative than positive
- Put in a "0" if they are approximately equal, and
- Put in a "?" if there is insufficient information to answer the question.

Option 1 : Status Quo	**Pro**	**Con**	**Final Assessment (+,-,?,0)**
Effectiveness			
Efficiency			
Equity			
Ease of Political Acceptability			

Option 2 :	**Pro**	**Con**	**Final**
Effectiveness			
Efficiency			
Equity			
Ease of Political Acceptability			

Option 3 :	**Pro**	**Con**	**Final**
Effectiveness			

Figure 4: Pro-Con Analysis of 4E's of Possible Options for Action

Unit 3: Engineering-Based Case Studies

The third module focuses on students applying these principles to engineering situations through case studies. The case studies were selected such that a variety of engineering fields are represented as well as the general issue of energy, a challenge likely to be the focus of interdisciplinary engineering activities. Currently, one case study was posted for testing (on 3D printing), but the others have been written and will be programmed in the spring and summer of 2016. The case studies were selected based on real situations analyzed by faculty members at Carnegie Mellon University, and uses videos by them to illustrate the concepts.

1. 3D Printing
2. Energy Efficiency
3. Energy Storage
4. Cyber Security
5. Electricity Generation
6. Sustainable Vehicles
7. Desalination
8. Energy Access
9. Organic Compounds
10. Edible Electronics

Figure 5 provides the executive summary from the 3D printing example:

Executive Summary: 3D Printing (focus on environmental impacts)

Category: Mechanical Engineering and Materials Engineering

Executive Summary:

3D printing, or additive manufacturing, is a technology that creates three-dimensional objects by successively layering material via computer control (3D printing process, 2014). There exist three common types of 3D printers: fused deposition modeling (FDM), stereo lithography (STL), and powder deposition printing (Ben Heck, 2014). FDM is the most common type of 3D printing. Traditional manufacturing methods include inkjet, computer numerical control (CNC) milling, and injection molding. Some advantages of 3D printing over traditional manufacturing methods include a reduction in material waste and an increase in manufacturing customization. Some potential disadvantages to 3D printing are the concerns about indoor air pollution emissions of ultra fine particulate matter, high energy consumption, and high use of plastics in an era when use of plastics is being discouraged.

Learning Outcomes: After completion of this module, students should be able to understand the mechanics behind policy analysis in the context of mechanical and materials engineering issues.

3D Printing NASA Image

Figure 5: 3D Printing Case Study

Videos

Working with an educational video company, Acatar, a spin-off company from Carnegie Mellon, we developed videos to teach the key concepts in the class. Based on the advice of the company, the videos were short (about 10-15 minutes) and each began with an illustrative "hook" with a real-world example, to encourage students to watch the rest of the video.

The videos proved much more popular than earlier versions of the module that were text only. There was some concern about duplicating material in the video in the text, but others appreciated the reinforcement of the concepts. The videos produced for the module include:

- What are policy analysis and program evaluation?
- How should you develop your policy analysis question?
- How should you develop and evaluate your policy options?
- How should you summarize your analysis?

The module also includes videos of faculty from different engineering fields describing why it is important for engineers to learn policy analysis. More videos are planned so that all fields are covered. Some student videos will be included as well.

Videos have also been produced but not yet incorporated into the module on benefit- cost analysis, risk analysis, and life cycle assessment. A video on prince analysis, a political analysis method, will be provided in the summer of 2016. These videos will be integrated into the existing module to illustrate how these analysis provide the information needed to evaluate the 4E's.

Use of the Module in the Classroom Setting

In the classroom setting, there are several ways the modules are used:

(1) **Policy-oriented Engineering Class:** Examples of this type of class are those in energy policy, environmental policy and politics, and new technology commercialization: public policy strategies (This last class is the subject of another ASEE paper). Students are first given a pre-quiz (for no credit) of the same 10 question multiple choice quiz given in the module. Students then learn the policy analysis principles in the module, practice them during in-class discussion of case studies and by writing blogs for their technology-based paper topic, and then produce a final 5-page policy paper at the end of the class bringing all their work together.

(2) **Technology-focused Engineering Class**: This type of class focuses on a particular technology such as carbon capture, cybersecurity, robotics, or water quality technology. Students may or may not do Unit 1 relative to what the faculty member believes the student does or does not know about policymakers and public policy. When it comes to Unit 2, focused on policy analysis, faculty members tended to pick a policy question they believed it is important for students to address relative to their class topic. In that way, they could focus on the most important public policy question facing their technology.

(3) **Engineering 101 Class:** This class, typically taken by freshman or sophomores, focuses on this topic in one or two classes as part of an overview of their major, say an "Intro to Civil Engineering" class. The instructor picks the question, and then teams of 3-4 students all address the same question in class using the module as the basis. Teams then can compare their policy results and options analysis to that of other teams. The key lesson learned in this situation as that policy analysis answers will differ and there is no one right answer. Students might identify the status quo and two policy options in one class, and then analyze those options in the second class.

Outcome Assessment

Students are assessed quantitatively before and after participating in the module with ten multiple choice quiz questions to assess what they have learned. They are also asked to provide information on the utility of the module and ways to improve it.

The module was used in several classes in the Fall 2015 semester, after a year of testing via a simpler Blackboard model the previous academic year. An ANOVA analysis of pre/post data for within subjects found that the effect on student's knowledge of public policy analysis was highly significant ($p < .001$) with post-test higher than pre-test. For the five questions that were more central to understanding of public policy concepts, the effects of the pre/post test were again highly significant. In addition, the effect of the question and interaction among questions were both not significant indicating that the variation in scores cannot be attributed to a particular question being wrong in the pre-test and correct in the post-test.

Students were also asked to provide feedback on the module. The findings are:

- Approximately 91% of the students found that the module was engaging/motivating to complete, and 100% believed it supported their learning.
- Students enjoyed the videos with real life examples the most, and getting to make decisions on public policy.
- Videos were far preferred over the text material.
- Students were asked on a 1 to 5 scale if they have a better understanding of the application of policy analysis for an engineering issue with 1 being low and 5 being high. The results indicate that 33% scored the module a 5, 58% a 4, and 8% a 3 with none at a score of 1 or 2.

Here are some illustrative comments from students regarding the module:

<u>Positive</u>

- The videos were good as they were short and to the point.
- I love videos as a learning tool.
- I like all the theories and find them very beneficial for lots of analysis.
- I learned a lot in the modules and thought they were beneficial
- Most of the courses should be done this way! The interactive, do at our own pace was great.

- It was a great learning experience and covered in depth what the class discussions were about.
- I thought the videos were well made and as an audio/visual learner it helped a lot.
- This taught me a ton!

Negative

- I think they were too long/given in too short of a timeframe.
- I'm not a fan of [online learning] in general.
- I thought it was very redundant.

Future Work

Additional analysis will be conducted on more classes in the 2016 spring semester. These are classes taught by the authors and those not taught by the authors. We have also asked faculty to test the module at other institutions so we may see if the effectiveness remains the same.

In addition, we will ask the students who used the module in earlier semesters whether or not the lessons learned were useful in other classes, internships, or employment. We have some informal feedback that it has provided useful in all of these situations, but we need to address the question in a more analytical fashion.

Bibliography

[1] Bardach, Eugene. *A Practical Guide for Policy Analysis: The Eightfold Path to More Effective Problem Solving*.
[2] http://www.abet.org/wp-content/uploads/2015/04/eac-criteria-2013-2014.pdf
[3] ABET, "Criteria For Accrediting Engineering Programs, 2016 – 2017," Accessed January 31, 2016 at http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/#outcomes.
[4] Kickstarter. Soccket at https://www.kickstarter.com/projects/unchartedplay/soccket-the-energy-harnessing-soccer-ball/posts/951293. December 8, 2014.
[5] National Academy of Engineering, NAE Grand Challenges for Engineering at http://www.engineeringchallenges.org/cms/8996.aspx.
[6] Nelson, David. *The Role of Government Policy in the Development of Solar Photovoltaic Power*. CPI Insight Series: Project Overview. San Francisco. 2011. See at: http://climatepolicyinitiative.org/wp-content/uploads/2011/12/Role-of-Government-in-PV-Power-Development.pdf
[7]Holland, Andrew and Cunningham, Nick. F*usion Power A Ten-Year Plan for American Energy Security*. American Security Project. 2014. See at: http://www.scribd.com/doc/233079041/Fusion-White-Paper-2014-10-Year-Plan-for-American-Energy-Security
[8]Burton, Elizabeth, Mateer, N., and Beyer, J. *California's Policy Approach to Develop Carbon Capture, Utilization and Sequestration as a Mitigation Technology*. Energy Procedia (37), 2013. See at: http://esd.lbl.gov/FILES/research/programs/gcs/projects/westcarb/CA_policy_on_CCUS_Burton_et_al.pdf
[9]Erisman, Jan. The European nitrogen problem in global perspective. Cambridge University Press 2011. See at: http://www.nine-esf.org/sites/nine-esf.org/files/ena_doc/ENA_pdfs/ENA_c2.pdf
[10] President's Council of Advisors on Science and Technology, "Realizing the Full Potential of Health Information Technology to Improve Healthcare for Americans: The Path Forward," 2010.
[11] West, Darrell, "Enabling Personalized Medicine through Health Information Technology Darrell West," Brookings Institution, January 28, 2011.

[12] Committee on International Security and Arms Control, National Academy of Sciences, "The Future of U.S. Nuclear Weapons Policy," 1997.
[13] Clark, D., T. Berson, and H.S. Lin, "At the Nexus of Cybersecurity and Public Policy: Some Basic Concepts and Issues" Committee on Developing a Cybersecurity Primer; Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences; National Research Council.
[14] Meeker, Daniella, J. Cerully, M. Johnson, N. Iyer, J. Kurz and D. Scharf. "SimCoach Evaluation: A Virtual Human Intervention to Encourage Service-Member Help-Seeking for Posttraumatic Stress Disorder and Depression." Santa Monica, CA: RAND Corporation, 2015.
[15] Chuong, Carolyn and S. Mead, "A Policy Playbook for Personalized Learning: Ideas for State and Local Policymakers," Bellwether Education Partners, June 2014.
[16] National Academies, "Advanced Research Instrumentation and Facilities," 2006.
[17] Quade, E.S., "The Systems Approach and Public Policy." Rand Corporation. P-4053. March 1969.
[18] Op. Cit. 1.
[19] Coplin, William D., and Michael Kent O'Leary. "Everyman's prince: A guide to understanding your political problems." Brooks/Cole, 1972.