Approaches to Integrating Policy into Engineering Education

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Approaches to Integrating Public Policy into Engineering Education

Abstract

Policy education has been deemed an important component in engineering and technology education. Several approaches can be taken to ensure that engineering students receive some education in policy. These approaches may range from a brief introduction to a comprehensive program integrating engineering and public policy; the goal of all these curricular interventions being to introduce the concept of public policy and promote an understanding of how policy and engineering are interrelated. This paper outlines various methods that may be employed to integrate policy into engineering and technology curricula. This paper takes a case study approach, describing some of the options and discussing the advantages and disadvantages of the various options. These case studies include modules, courses, a certificate program and a study abroad experience.

Introduction

The importance of including policy education in the engineering curriculum has been recognized by experts from bodies including the Accreditation Board for Engineering and Technology (ABET), the American Association for the Advancement of Science (AAAS)[1], and the National Academy of Engineering (NAE)[2, 3]. Engineers have a dual role in public policy: helping to create public policy related to the use of technology and monitoring and assuring compliance with such policies, and using engineering knowledge to assist in the construction of policy directives to help solve social problems. The increasing proliferation of scientific and technological artifacts into society creates an increased need to regulate the use and distribution of these artifacts. An understanding of the functioning of these technologies and how the various technologies interact with social systems is necessary for the development and implementation of efficient regulations and laws and so requires the involvement of a technical expert. The increasing utilization of engineered artifacts has also produced macro-scale problems such as climate change that exist in and are connected to complex situations (e.g. global production chains) that are also the result of engineering advances. These problems require engineering involvement in the search for their policy solutions. Even though the need for closer collaboration between technical experts and policymakers is increasing, the divergence between the two is increasing because scientists and policymakers differ in their aims, attitude and process[4].

Though there is a clear need for engineering knowledge and participation in both of these public policy agendas, the participation of engineers in public policy has remained low. While scientists and engineers are as or more likely to participate in political processes in their private lives than the average citizen, e.g. by voting; as a group they are reluctant to engage in public policy processes. A report from the Committee on Science, Engineering and Public Policy[5] revealed that only approximately 22% of those considered science and technology policy leaders hold an engineering degree. A series of surveys conducted by Miller [6, 7] over several years from 1985 to 2002 show that even when scientists and engineers hold positions related to public policy that qualify them as policy leaders, only a third actively attempt to influence political action through conventional means.

The lack of engineering participation raises the question of why engineers are not interested in public policy endeavors. A study by the Committee on Science, Engineering and Public Policy[5] reports that high ranking government positions in science and technology policy are not popular among scientists and engineers because these positions are perceived as being low in prestige and lacking in opportunities to effect meaningful change. In addition to severe restrictions on post-appointment employment and involvement in other projects, these jobs involve increased public scrutiny and loss of privacy, making them seem undesirable.

Negative attitudes towards public policy participation can be seen much earlier. An exploratory study carried out by Sicker and Lookabaugh[8, 9] with engineering undergraduates found that students were resistant to public policy discussions because they felt that the topics were irrelevant to their engineering program and that their level of contextual knowledge did not allow them to fully understand the discussions. Other engineering students have expressed related discontent with discussions regarding public policy because unlike many of their classroom engineering problems, public policy problems often do not have cleanly bounded definitive solutions. Professors, understandably, also generally look unkindly upon anything they perceive as detracting from time that could be spent covering technical material since curricula are already overloaded.

It should be noted that though there are challenges to integrating public policy into engineering curricula, there are also benefits beyond developing student interest and expertise in the policy area. Discussions of public policy in engineering/technology could serve to increase students' continued interest in engineering. A number of studies have demonstrated that many students drop out of engineering because while they chose engineering careers because of the expectation that they would be able to help people, during their studies they find a lack of opportunities to do so [10, 11]. These students are assumed to be searching for ways to use technical material to contribute positively to society. This opportunity to benefit society is one of the main attractions for students, at both undergraduate and graduate levels, to biomedical, environmental-ecological, and agricultural-biological engineering disciplines[12]; it is especially noteworthy that these engineering disciplines also have the largest ethnic and gender diversity in enrollments. Engineering/technology and public policy could serve as a method to maintain these students' interest in engineering because of its socially focused nature [13].

Despite resistance among engineering students and faculty, engaging students in public policy learning and discussions should be encouraged. The National Academies report on Educating the Engineer of 2020[14] outlines this as one of the goals that should be pursued by engineering educators.

> As technology becomes increasingly ingrained into every facet of our lives, the convergence between engineering and public policy will also increase. This new level of interrelatedness necessitates that engineering, and engineers, develop a stronger sense of how technology and public policy interact. To date, engagement of engineers in public policy issues has been limited at best. It is both the responsibility of engineers and important to the image of the profession that engineers increase their ability to eloquently articulate the relevance of engineering to many public policy issues. In parallel with this, it is critical to try to improve public understanding of engineering, so that the public can

appreciate the value and consequences of new technology and meaningfully participate in public debates where technology is a critical factor.[14]

Clearly there is an important role to be filled by engineers in the public policy arena, but this role is instead being filled by graduates of law, business, and social science programs. Engineering programs are beginning to recognize this need and are responding with the establishment of courses and programs in engineering and public policy. The need for engineers able to engage with public policy, along with the growth in such programs raises the question of how best to prepare engineers to fill these roles.

Though there are a few programs that focus on engineering, science, and technology policy, and few more that offer individual courses on the topic[15], the majority of these courses are intended to provide exposure to the ideas rather than seriously engage students with authentic policy problems or prepare them for careers in this field. In order to actually consider policy implications to engineering/technology design or be effective in the public policy arena, engineers need more than a brief exposure to social science material. They need to: have a rudimentary understanding of related topics in other fields; be able to communicate to stakeholders at different levels of government, industry, etc; be able to effectively engage with and educate (and be educated by) the public; be able to communicate and integrate effectively across disciplinary boundaries; have knowledge of policymaking process and motivation to engage in it; be able to maintain credibility and ethical standards; be able to recognize and extrapolate social, environmental, etc consequences; and be able to work at both micro and macro scales[16]. However, there is very little guidance on how to integrate policy discussions and analysis into the classroom to achieve these attributes.

Several approaches can be taken to ensure that engineering students receive some education in policy. These approaches may range from a brief introduction to a comprehensive program integrating engineering and public policy. However, the goal of all these curricular interventions is to introduce the concept of public policy and promote an understanding of how policy and engineering are interrelated. This paper will outline various methods that may be employed to integrate policy into engineering and technology curricula and use Purdue University as a case study to examine these methods in greater depth.

Purdue University has a large population of engineering and technology students and has recognized the need for more policy inclusion in the curriculum. However, it is difficult to add policy courses to the engineering and technology curricula firstly because these curricula are already packed and secondly because there is a large variation in students' interest in and prior knowledge of policy topics. Therefore, Purdue University has taken a flexible approach, providing students with a diversity of options to introduce policy knowledge. These options differ in their length, the instructional approaches used, the depth of coverage of the various policy topics, and the range of content covered. This paper will take a case study approach, describing the options and discussing the advantages and disadvantages of the various options.

Comparing methods of policy learning

There are several methods that can be used to introduce policy into engineering and technology education. These range from full programs in engineering or technology and public policy in which students can earn a degree, to short talks outside of class or modules within a class that simply introduce students to an interesting new idea. These methods require different levels of expertise and commitment from the instructor and assume differing levels of prior knowledge from students. Of necessity they vary in length and therefore, the depth and breadth of the content knowledge they can address. An exhaustive list cannot be provided here but for the purposes of this paper the definitions below are provided of some of these approaches.

- *Talk/seminar:* A talk or seminar is a singular, short (usually 45 minutes – 2hours) experience during which a speaker or pair of speakers familiar with a topic provide an overview of the topic and discuss some aspect of that topic. The substance of the talk/seminar is usually a report of the speaker(s) work.
- *Module:* A module is a short treatment of a policy topic, usually occurring within a larger class. Modules usually take place over 1-3 course periods.
- *Workshop:* A workshop is an in-depth treatment of a specific topic, usually occurring outside the regular classroom setting. Workshops usually last 2 hours – 2 days.
- *Exposure Experience:* An exposure experience is an experience designed to introduce the learner to the topic through an authentic/real world contact. These experiences include field trips, internships, and some study abroad experiences.
- *Focused Course:* A focused course is a trimester or semester long experience, usually for credit that addresses a set of related topics with the goal of incre4asing the learners' expertise in those areas. The course generally includes a range of learning experiences e.g. lectures, projects, etc. A focused course could include modules, talks and exposure experiences.
- *Survey Course:* The survey course is a trimester or semester long experience designed to introduce the learner to a broad range of topics around the same area, the goal being familiarity with different topic areas rather than expertise. While the course may include a range of learning experiences, the basis of the course is usually a series of talks.
- *Certificate:* The certificate is a means for students to proficiency in a topic area. It usually comprises of a selection of 3-12 courses generally taken as part of a larger degree course.
- *Program:* The program is a means for students to acquire an in-depth understanding of a subject. Usually comprises 1-5 years of coursework and related experiences e.g. a dissertation, survey courses, focused courses, exposure experiences, etc.

Shorter approaches such as talks do not allow for much breadth or depth. Modules and workshops, if focused on a single topic may not allow for much more breadth of coverage than a talk but do allow for greater depth. Survey courses, on the other hand, are designed to cover a broad range of topics though students would not learn more than the basics about each one. Depending on how they are structured, exposure experiences like internships and focused courses can vary widely in the span of knowledge covered and the extent to which each topic is examined. Figure 1 provides a summary of the breadth/depth relationships for these approaches.

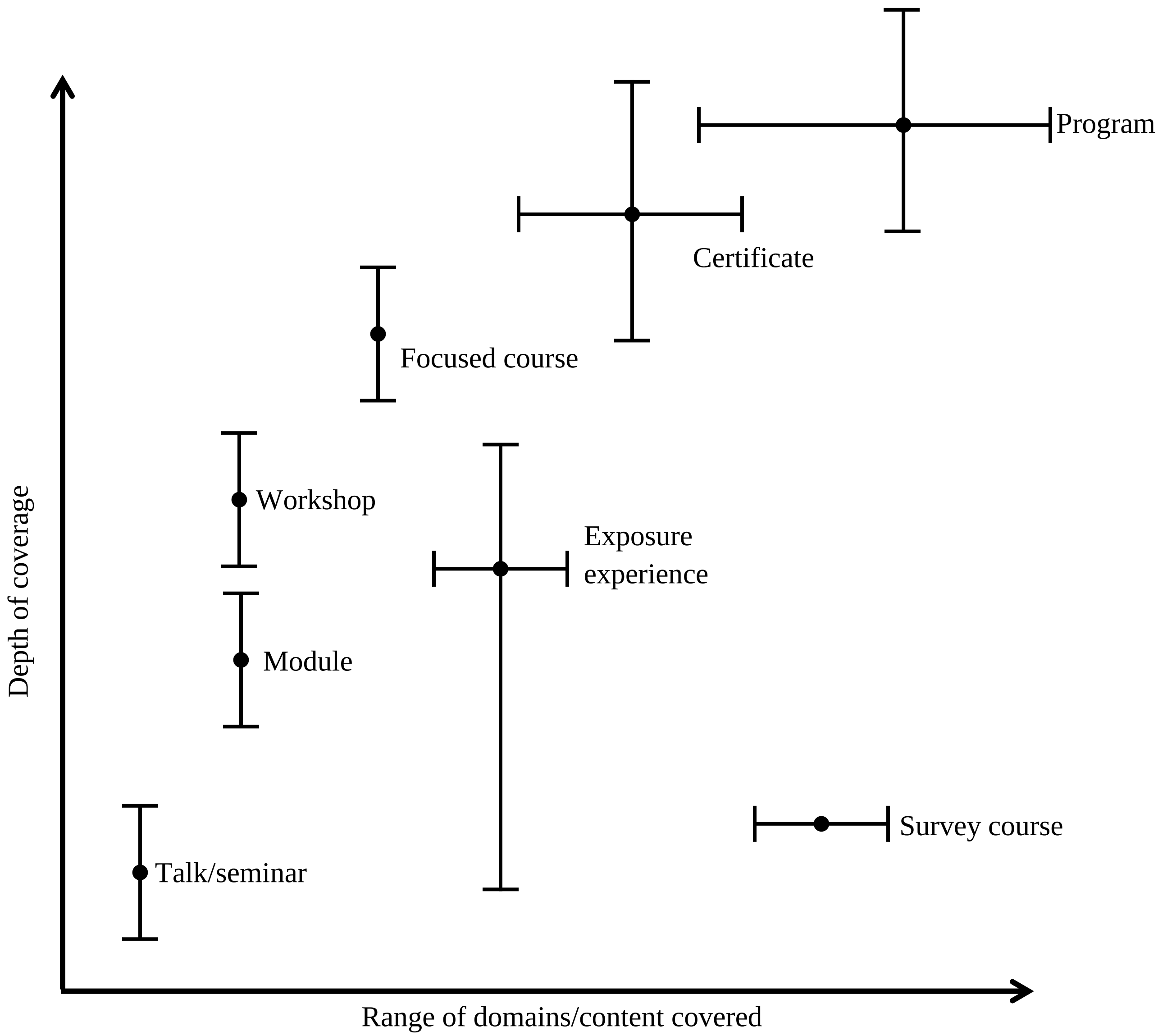

Figure 1: Chart comparing depth and breadth of content afforded by various learning experiences

Having this range of approaches to choose from is beneficial to both student and instructor because it provides flexibility for student learning. Each approach presents different pedagogical affordances for example an important principle of learning is for students to have an understanding of facts and ideas and be able to contextualize this knowledge within a framework in a way that allows for both retrieval and application[17]. Applying new knowledge helps students to place knowledge in context and fix the knowledge in their mind[18]. Another important principle of learning is metacognition which helps students to take control of their learning[17]. Modules or courses can serve as a good way to transmit a great deal of factual information; exposure experiences allow students to apply and contextualize knowledge; and longer experiences like courses and programs give students time to reflect on their progress and provide more opportunities for them to control their learning.

Bloom's taxonomy provides another way to demonstrate the affordances of the different approaches to policy learning. In this taxonomy there are four types of knowledge viz. factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge[19]. Programs and certificates can cover all these forms of knowledge where talks and seminars may only cover one domain such as factual knowledge. The same can be said for the levels of intellectual behavior outlined in the cognitive domain of Bloom's taxonomy (i.e. remember, understand, apply, analyze, evaluate, and create); exposure experiences, for example, can provide the opportunity to apply knowledge where a talk would only give the opportunity to remember and possibly understand knowledge. Therefore, when choosing an approach to policy education in engineering or technology, it is important to recognize the affordances and limitations of each approach. The instructor must weigh the time and resources available as well as the desired objectives against the types of knowledge and the levels of intellectual behavior offered by each approach. Figure 2 displays the various learning approaches in the context of Bloom's taxonomy.

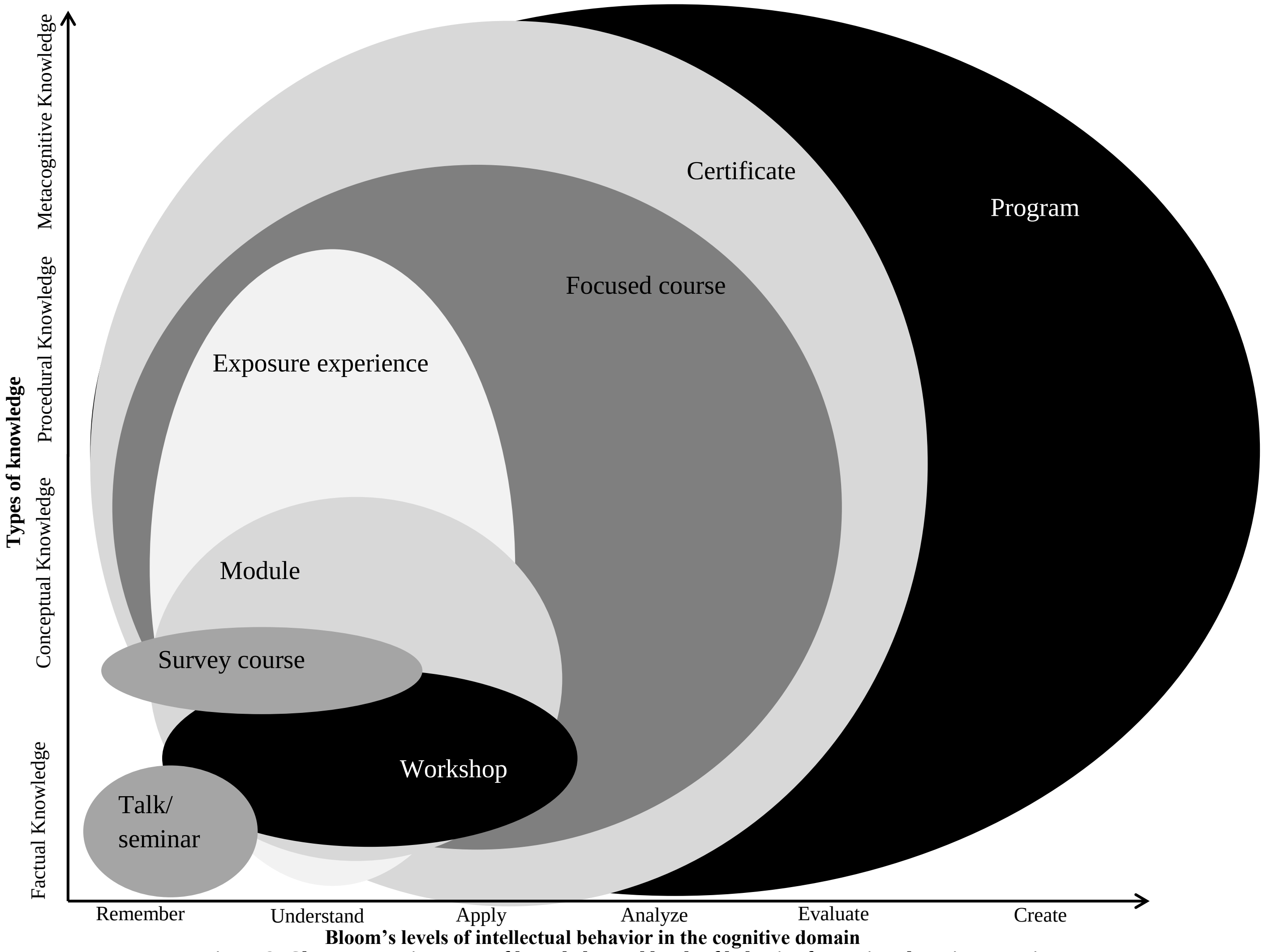

Figure 2: Chart comparing types of knowledge and levels of behavior for various learning experiences

Case Studies demonstrating learning approaches

Like many institutions Purdue University has recognized the need to address policy questions in the engineering and technology curricula. In response to this need, Purdue University has taken a number of approaches including the development of modules, courses, study abroad experiences and a certificate program. We will use descriptions of four of these instances as examples to demonstrate the approaches described above.

Technology and Public Policy Course

Science and technology intersect with myriad areas of public policy for example the regulatory failures behind patient deaths from Vioxx; the challenges associated with regulating the protection of genomic information used in personalized medicine; the debate over the reality and extent of climate change; and widespread public perception of eroding American research and development competitiveness in a globalizing world. Discussion of these salient issues often turns back to a common set of questions about the relationship between science, technology and policy. Is scientific and technological development a force beyond human controls, or can it be governed? Is more and better science necessary for public political decision making? Is the furtherance of scientific understanding always socially benign, and who decides?

The Technology and Public Policy course examines such questions by surveying the variety of interactions between science, technology, and policy. Because federal, state, and local policy agencies are entrusted with translating scientific and engineering progress into programs and solutions that benefit society, its institutions, and its people, the course focuses on how science and technology policy relate to challenges to our quality of life – security, economy, environment, health, education, transportation, communication, etc. The course considers the process of translation – the interplay of interests through the apparatus of government to produce "public policy." Because a social context is needed for grounding policy studies, the course focuses primarily on the American context, but comparative perspectives are welcome and included. The goal of this course is to provide a class that is useful for students in a variety of science, engineering and technology majors. As such, the approach is multidisciplinary, drawing upon literature in a wide range of disciplines including political science, philosophy, economics, sociology, and history. The outcomes for the course are to provide students with:

- Background on science and technology policy environment
- Multidisciplinary toolkit for thinking about science and technology policy
- Multidisciplinary methods for influencing science and technology policy
- Understanding of the "social science" of science and technology policy
- Expertise in conducting and presenting policy analysis

The course uses a seminar format where the function of the seminar is to bring together the learners for recurring meetings (classes) focusing each time on some particular subject in which everyone present is requested to actively participate. The particular subjects in this class are organized into the following themes:

- An Historical View of Science/Technology and Policy

- Participants in Policy Making
- Policy Goals
- Evolution of Science and Technology Policy in the U.S.
- Policy Sources of Technical Change
- Contemporary Issues in S&T Policy
- A More Contextual, Dynamic View of Policy and Scientific/Technical Innovation and Industrial Change
- Evolving Issues in Science and Technology Policy

Learners' participation is often accomplished through an ongoing Socratic dialogue with the seminar leader or through more formal presentation of research. The pedagogical idea behind the seminar is to familiarize students more extensively with the methodology of the subject, allow them to interact with examples of practical problems, provide a place where questions can be asked and debates can be conducted. In contrast to delivering the content via lecture, the participative nature of seminars fosters social learning, which aligns to policy learning as policy is inherently a social process.

Global Policy Seminar Course

Changes of global dimension are generally highly complex, disruptive, and interconnected. Responses to such problems as climate change, energy sustainability, invasive species, pandemics, food security and terrorism require international cooperation and diplomacy in policy development. Developing such policies relies on new knowledge and scientifically-informed policy options. In 2009, a group of faculty members identified the need for a significant policy experience for undergraduate students. The faculty members were part of the Faculty Leadership Council from the Global Policy Research Institute and researchers in science and technology relevant policy. The first course offering of the ***Global Policy Seminar*** was designed to be interdisciplinary and include majors from four of the academic colleges on campus. This included Agriculture, Engineering, Liberal Arts, and Technology. Today the course has expanded to include eight academic departments. The course provides an experience and background for students seeking career leadership opportunities in academic, governmental and international corporations where an interest and understanding of global issues is essential.

Students enrolled in the ***Global Policy Seminar*** course learn about the scope of contemporary global issues, pacing public policy developments, the role of science in providing policy options, and the contributions of researchers and research findings in informing and advancing policy developments. The course also presents examples of interconnections among global, national, state, and local responses to global issues.

The course employs inquiry-based learning throughout the semester. A significant component of the learning process involves student classroom participation and working collaboratively in teams. After an initial set of lectures on policy making and the role of economics, human factors, and technology in the policy development process, seminar sessions are conducted by faculty leaders engaged in globally-relevant research. The first sessions are a general overview by the instructor of a global issue and the role that research is playing to address the issue. Interactive classroom team discussions are conducted to illuminate global grand challenges in the course theme areas, alternate policy options and the consequences of these options. Student teams are assigned a major course term assignment to develop a brief (7-10 page) policy analysis to address one specific aspect of a global policy issue of the team's interest. Student teams follow a predetermined sequence in analyzing, evaluating and making recommendations. The six step process is as follows:

1. Issue identification
2. Identification of policy alternatives to address the issue
3. Analysis of each alternative to determine its consequences both positive and negative
4. New policy development
5. Policy implementation
6. Policy evaluation and identification of new issues

Each team is required to present the team analysis and be prepared to defend their analysis and recommended alternatives.

Global Policy and Innovation Study Abroad Seminar

There are numerous opportunities for students to have a significant international experience at most colleges and universities. Today students are exposed to international students and cultures on virtually every major university campus and in the classroom. They are also exposed to faculty members and graduate students from other countries and cultures during their educational experiences. They can also pursue another language and learn from visiting scholars and invited lecturers from other parts of the world.

However, there are other important international opportunities available to students. One is the semester or yearlong study abroad or student exchange programs at a university in another country. A second option is the short duration study abroad programs offered during the academic year or during the summer. The Global Policy and Innovation Study Abroad Seminar falls in the category of a short duration program offered during the summer.

The grand challenges facing our world today are extremely complex, often disruptive, and globally connected. These global challenges and problems are often referenced as “Wicked” challenges or problems. Solutions to world problems such as energy, climate change, health, security, food and water will require global collaboration in developing effective policy and innovation solutions to address these issues.

Thought leaders in science and technology play an increasingly important role in providing new knowledge and viable alternatives and solutions to the World's grand challenges. Some of the grand challenges for the European Union and United States are topics that touch upon the timely interlocking issues of sustainability, energy and the environment, health care, climate change, food security and safety, and information security. Toward this end, a key question is how to foster innovation for sustainable growth and the creation of high-quality jobs, while remaining sensitive to important societal issues of efficiency, equity, liberty and security.

The study abroad program focuses on the role of a Global Science and Technology community in shaping, implementing, and evaluating alternatives to address global problems and challenges.

This is in alignment with the mission and vision of most globally connected and focused colleges and universities.

The primary objective of the Global Policy and Innovation Study Abroad program is to expose students to policy organizations and development in the European Union as compared to the United States, and familiarize students with transnational policy bodies and issues. The comparative approach focuses on the state's capacity to bring about reform, concentrating on the political feasibility of formulating, implementing, and consolidating policy change. More specifically, the course considers how similarities and differences in policy outcomes are influenced by three elements: 1) the political-economy context of the respective country, 2) the policy processes, and 3) the political strategies used. A major objective is to help students better understand how policy is developed in a union of sovereign countries sharing a common currency in comparison to the United States, which is a union of federated states who also share a common currency. The role of the science and technology community in the policy development process is also discussed and emphasized.

The European part of the program begins in Darmstadt, Germany at Darmstadt University. The second phase is in Strasburg, France, which is the Headquarters of the European Parliament. The third and final phase takes place in Paris at OECD (Organization for Economic Co-Operation and Development OECD).

Study Abroad Format:

1. The program serves between twenty and twenty-five undergraduate or graduate students.
2. The targeted student populations for the program are majoring in political science, economics, agricultural economics, technology leadership and innovation, computer and information technology, mechanical engineering and nuclear engineering. The program is also open to all upper level undergraduate and graduate students.
3. Guest speakers deliver presentation on policy topics, with student participation being an important element in the overall learning process. Speakers and faculty leaders from Darmstadt University, European Union Parliament Headquarters in Strasburg, France, and the Organization for Economic Co-operation and Development in Paris, France are part of the program.
4. Students are required to maintain a journal and complete a final report, which is presented at a final meeting upon returning to the United States.
5. Student Teams select a policy and innovation topic to research and present.
6. Students will receive three hours of credit upon successful completion of all assignments.

Certificate Programs

Certificate programs are typically non-degree programs designed to provide students with specialized knowledge that is less extensive than, and different from, a bachelor's or master's program. The rise of certificate programs is in part due to continuous and more rapid changes in the knowledge and skills needed in the workforce. As business and industry continuously change due to innovations in technology and management philosophies, the skills necessary to perform many every day job functions have changed just as rapidly. These new job-demands, and the competitiveness of today's job market creates the need for learners continually upgrade skills through flexible and adaptive educational programs; certificate programs are one method of doing so.

Purdue University has several certificate programs; three of the most recent and most relevant to this paper are Information Security Policy, Environmental Policy, and Industrial Engineering and Systems Policy. The respective certificates share a common core in two classes focused on policy; one on the social context of policy making and the second on policy tools. The rationale for the policy context class is that each student who obtains the graduate certificate in public policy should have some basic knowledge about policymaking somewhere (i.e., the United States, the European Union, Nigeria, whatever institution, place or context is most important for their field of study). The purpose for the policy tools class is that each student who obtains a graduate certificate in public policy also ought to have a basic understanding of some of the most common tools used in policy analyses, such as statistical analysis, qualitative analyses (such as focus groups and case studies), and cost-benefit analysis.

Thereafter, each certificate has three classes focused on the cognate area of information security, environment, and industrial engineering respectively. The appropriate cognate classes are linked to the respective field of practice. In response to demands from government and industry, Purdue University launched an information security masters degree in 1999 and a doctoral degree in 2006. Some of the interdisciplinary information security graduates are taking positions in the public sector, i.e., defense and civilian agencies, where they are expected to have working knowledge of policy making and policy analysis as applied to information security. For example, the purpose of the graduate certificate in information security policy is to offer a practitioner-oriented credential in this emerging area to students who are 1) pursuing a Masters or Doctoral degree and 2) working professionals seeking career professional development. The cognate classes in the information security policy certificate include focus on relevant policy issues in information security, such as how policy factors into grand challenges in information security as well as relevant policies, laws and regulations that information security practitioners need to know.

Conclusion

Policy education has been deemed an important component in engineering and technology education. Several approaches can be taken to ensure that engineering students receive some education in policy. These approaches range in length, form and intensity and therefore in the breadth and depth they afford. Therefore, in order to select/design the appropriate experience an instructor must weigh the time and resources available as well as the desired objectives against the types of knowledge and the levels of intellectual behavior offered by each approach. The optimal learning experience for students will usually involve some combination of approaches. The examples described at Purdue University display several different approaches, each with its own set of learning objectives. As demonstrated by these descriptions, the requirements for each course are different and are designed for the particular objective. In order to design a meaningful learning experience, the educator must first identify the objectives for the learner and consider the constraints within which these objectives are to be achieved[20]; based on these criteria, the appropriate learning setting can be chosen. It is hoped that the discussion of the affordances of various learning experiences outlined here as well as the examples of how these can be translated into courses provide a useful guide to aid these selections.

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