Evolution of Engineering and Public Policy Undergraduate Program at Carnegie Mellon University

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Evolution of the Engineering and Public Policy Undergraduate Program at Carnegie Mellon University

The undergraduate program in Engineering and Public Policy at Carnegie Mellon University is a unique additional major program for students earning a BS degree in a traditional engineering field. Started in 1969, the program continues today with the aim of expanding the skill set of traditional engineers to better address today’s technological issues as they relate to society and policy. The premise of the undergraduate program in EPP is that engineering does not operate in a vacuum separate from society. The program has been educating engineers to broadly approach engineering problems, to work effectively in multidisciplinary teams, and to consider non-technical perspectives, long before the characteristics of the “Engineer of 2020” was ever defined.

This paper discusses the EPP program over its four decades and how the program integrates with the traditional engineering programs. We discuss the curriculum over time, the course selections students make, and the benefits our alumni receive from the program. We will give an overview of our capstone EPP Projects course, a truly interdisciplinary teamwork situation addressing current technology issues. Finally we reflect on how the program achieves the ABET (a) through (k) outcomes and work in the ABET system, and how the program has been successful these past 40 years.

We do not expect other institutions to duplicate our program necessarily, as it requires a culture of interdisciplinary collaboration and extensive commitment at all levels of the university for success and longevity. However, we want to share the elements of our curriculum and courses with others with similar endeavors (certificate programs, minors) and with others considering creating broad interdisciplinary courses across majors. Our experience can guide decisions for developing these programs and courses and help deal with the challenges these programs and courses might have.

The Engineering and Public Policy Program

The original program in EPP was a BS in Engineering and Public Affairs, a stand alone degree where students had experience in both technical courses and social and political systems (see Dunlap and Lewis, 1974 for details on the origin of the program). The degree could also be an additional major for students electing to complete the full requirements for a traditional engineering major. Students were expected to have sufficient expertise in both engineering and the social sciences, not a few classes in one or the other that did not provide depth. The program included a summer internship between junior and senior year where students were expected to work at government or industrial organizations and gain first-hand experience of how technological factors are constrained by economic, social, and political factors. Only four students received the stand alone major BS in Engineering and Public Policy (and the first to do so had earned a BS in a traditional engineering field the prior year). Advisors were finding
themselves encouraging students to complete the 2-3 additional courses of the traditional engineering degree programs, in order to become full-fledged engineers. This would open further options for careers for the students. The decision was made in 1984 to eliminate the single-major EPP degree program and offer the EPP degree only as an additional major.

Since 1984, all students complete the program in a traditional engineering major, and pursue the EPP degree as an additional major. Course requirements have changed only slightly in the forty years of the program. Students use their general education units and free elective units to take the courses required for the EPP degree. The program in EPP runs independently of the other traditional engineering programs, although the departments coordinate with each other on administrative tasks such as student advising, course scheduling, and accreditation. The EPP program is accredited “in conjunction with a traditional engineering program” by ABET. Students are expected to achieve the fundamentals of technical engineering skills in their traditional majors all of which are accredited, while the EPP program adds an extra dimension of how engineering operates in the real world above and beyond that. The EPP program has graduated just over 800 graduates since its inception in 1969. Between 6%-10% of the engineering students at the university complete the undergraduate degree.

**Engineering and Public Policy Courses**

The EPP curriculum has had to adapt over the years as the college has changed general education requirements, and as traditional engineering programs have changed their math, science, and engineering requirements. The EPP program has always been designed to be completed within the traditional 8-semester timeframe of undergraduate engineering education. Some additional units are necessary, but the program has avoided requiring additional courses above those required for the traditional majors. Table 1 lists the general curriculum for the EPP undergraduate program over the past 40 years.

Table 1. Curriculum of the Engineering and Public Policy Program. Numbers in parentheses indicate the number of courses of that type required.

|-----------|-------------|----------------------------------------|
Three sets of courses have always been a part of the curriculum: core social science area courses, technology-policy electives, and projects courses. The EPP Projects courses are discussed in the following section. In the social sciences, students must take courses in economics, decision sciences, and statistics. The core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. Students have also been encouraged, and are now required, to take a course in technical writing. Basics of public policy are included in the Introduction to EPP course and EPP Sophomore seminar. Students may also take general education courses with policy emphasis.

EPP Technical electives, or now Technology-Policy electives, are technical in nature and demonstrate those connections between technical/engineering issues and society. Courses are one of two types. First, Technology-Policy courses are those that synthesize engineering analysis and social analysis perspectives and apply them to problems with substantial societal technological components. Courses in this domain have included over time:

- Law and the Engineer
- Risk Perception and Communication
- Science, Technology and Ethics
- Policies of Wireless Systems and the Internet
- Information Warfare
- Global Competitiveness: Firms, Nations, and Technological Change
- Privacy, Policy, Law and Technology
- Environmental Science, Technology, and Policy
- Energy and the Environment
- Climate Science and Policy
- Water Technology Innovation and Policy

Second, courses that teach methods or background vital to classes of important problems at the technology - society interface are included. These include courses such as Optimization, Air Quality Engineering, or Fundamentals of Electric Power Systems.

These EPP Technical or Technology-Policy electives are often taught by faculty with joint appointments in Engineering and Public Policy and another traditional engineering department or a social science department. Courses are often cross-listed among departments as well, with students of various backgrounds enrolling the courses under different course numbers to fulfill different course requirements of their respective majors.

**EPP Projects - A “Real World” Capstone**

The capstone “design” course for the EPP program is the EPP Projects course. These courses have existed since the program’s inception. In each project course, students work in
multidisciplinary teams on a “cutting edge” project topic with very little in the way of “pre-digested” analysis or solutions. Project faculty attempt to choose topics with both technical and social dimensions, requiring multi dimensional analysis. The issues are ill-defined and complex, open-ended problems where multiple perspectives are essential for moving forward. Students are given a general goal, and are expected to discover existing knowledge on the topic, to research existing policies relevant to the topic, and analyze alternatives that make society better off. Using this background research, and their technical and social analysis education as appropriate, the students then create new knowledge on the subject. This knowledge is communicated to an external advisory panel, selected from experts and constituencies of importance to the issue. Students give interim reports during the semester, after which the advisory panel may make suggestions on direction and scope of the work. A final oral report is presented to the panel along with a written report at the end of the semester.

The course is truly multi-disciplinary, as it serves as the capstone not only for EPP, but also for students in the Policy and Management program of the Social and Decision Science Department. Students from the Heinz College Masters in Public Policy and Management program may also select the course to fulfill a project course requirement. The course thus regularly includes undergraduate engineers and humanities and social science students, and graduate students in public policy. Each student brings a unique background and skill set to the course. Students must learn as part of the course to work with these other students “who think differently from themselves” and be able to communicate with these other students.

Students in EPP are required to take this course twice. The first time through, students are novices to project-type learning. Students often struggle with the approach of the class as it is open ended and loosely structured, without regular homework and tests, and to some extent with the students themselves guiding the course. The second-time students often take on group leader roles, helping the first-time students navigate the structuring of a complex problem.

The course addresses all of the ABET (a) through (k) outcomes to some degree, and does so within the broader context of a real-world problem. The specific course objectives are:

1) Decomposing, structuring, and formulating solutions to unstructured problems.
2) Assessing what can be done and delivering a product on time.
3) Interdisciplinary problem solving: Data collection, analysis, and synthesis, formulation and evaluation of policy recommendations.
4) Developing professional oral and written communication skills through participation in oral presentations, and preparation of the final written project document.
5) Developing the ability to function on multidisciplinary teams.

These course objectives are independent of the content and topic, or what specific activities and responsibilities a particular student takes on. Typically, the students organize themselves into groups of 4-6 students tasked with deep investigation of a subset of the problem. For example, one group may pursue a technology assessment of potential solutions, while another group may develop and deploy a survey to gain stakeholder feedback, while another will complete an
economic analysis. Together, the group results provide a complete picture of the problem and potential solutions. Recent topics for the EPP Projects course are listed in Table 2.

Table 2. Recent Engineering and Public Policy Project Course Topics.

<table>
<thead>
<tr>
<th>Project Date/Title</th>
<th>Client</th>
<th>Project Description</th>
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<tbody>
<tr>
<td>Spring 2013 “What are the Prospects for Natural Gas Vehicles in the Pittsburgh Region?”</td>
<td>Public, Foundations, Business, Industry, Government Policymakers</td>
<td>This project investigated the potential for replacing liquid petroleum based transportation fuels with natural gas in the Pittsburgh region.</td>
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<tr>
<td>Spring 2013 “Advancing Wind Energy”</td>
<td>Public</td>
<td>This project aimed to determine the potential for wind energy as a primary source of renewable energy growth in the U.S. given the current state of opposition to wind power development.</td>
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<tr>
<td>Fall 2012 “Bridging the Digital Divide”</td>
<td>Pittsburgh CONNECTS</td>
<td>The project developed methods for evaluating programs seeking to reduce the &quot;digital divide,&quot; which separates communities with and without ready Internet access, and evaluated digital divide programs in Pittsburgh.</td>
</tr>
<tr>
<td>Fall 2012 “The Locks and Dams Crisis”</td>
<td>Port of Pittsburgh Commission</td>
<td>This project analyzes the state of locks and dams on waterways of the Pittsburgh region and their value to commerce and economic development in Southwestern Pennsylvania.</td>
</tr>
<tr>
<td>Spring 2012 “Vehicle Use, Transportation and Energy Policy”</td>
<td>Public</td>
<td>This project examined the transportation and energy in the U.S. based on the study of regional stock of Pennsylvania registered vehicles over 10 years, census data and state-wide surveys.</td>
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<tr>
<td>Spring 2012 “Emergency Messaging with Social Media”</td>
<td>Public</td>
<td>Students investigated the current and potential use of social media in emergency messaging in the USA.</td>
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<tr>
<td>Fall 2011 “Risk Evaluation and Mitigation Strategies (REMS)”</td>
<td>Public</td>
<td>The project examined how consistently the US Food and Drug Administration Risk Evaluation and Mitigation Strategies (REMS) are applied, along with how to evaluate and improve their effectiveness.</td>
</tr>
<tr>
<td>Fall 2011 “The Effects of Regional Energy Production on Water Quality in Southwestern Pennsylvania: Past, Present and Future”</td>
<td>Public</td>
<td>The project investigated the relationship between regional energy production and regional water quality in southwestern Pennsylvania, past, present and future, emphasizing the current environmental concerns related to shale gas development.</td>
</tr>
<tr>
<td>Spring 2011 “Trends in the US Vehicle Fleet across Economic, Safety, and Environmental Measures”</td>
<td>Public</td>
<td>This project investigated how trends in characteristics of the US vehicle fleet have affected overall safety and environmental impacts.</td>
</tr>
<tr>
<td>Spring 2011 “Green Printing: Reducing Waste and Innovative Alternatives to Printing”</td>
<td>Public</td>
<td>This project investigated opportunities for reducing printing on {Institution X} campus considering reasons for printing, amount of printing, and incentives to reduce and technological alternatives to printing.</td>
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Career Paths for Engineering and Public Policy Graduates

Students who pursue the additional major in Engineering and Public Policy graduate with a regular accredited engineering degree in a traditional engineering major. Thus, all options for traditional engineers remain. The majority of our graduates pursue and start a traditional technical career, similar to their non-EPP major counterparts. Graduating seniors report, however, that the additional major in EPP sparks an interest with recruiters and interviewers and becomes a main focus of their interviews. Students talk about the added set of skills and perspectives gained from the program, discuss their EPP Projects course experiences, and explain how the major puts their engineering learning in context. Students often take the reports from the EPP Projects course to interviews to show their abilities to communicate in written form, and their experience with working within a team to contribute to a larger project. Employers recognize and appreciate these skills. The additional major acts as a differentiating point for the students - as a Carnegie Mellon University engineering graduate they are known to have good technical skills, so the EPP degree provides those non-technical elements to make the student a better candidate for the job.

Some students pursue non-traditional engineering positions. Few at the undergraduate level seek policy analysis jobs in government or public policy consulting firms, although they are qualified. Some seek positions in corporations where dealing with government regulation or policy is a part of the position, for example environmental health and safety areas, product liability and safety areas, or the like. Many students complete Masters programs (integrated 5-year or follow-on programs) in their same traditional engineering field prior to entering the workforce.

Of our approximately 800 alumni, the most common job titles include “engineer” (135) and “manager” (70). These include all levels (Senior, principal, etc.). The list is otherwise representative of a typical engineering program with executive officers, owners, attorneys, consultants, professors, teachers, and non-engineering careers. Most students work in industry, with less than 50 each working in government, academia, and other areas.

Educating the Engineer of 2020

Students in the EPP program become “engineers with a difference.” As suggested by the NAE Educating the Engineer of 2020 report, our program challenges students with real-world problems that span disciplines, including non-technical disciplines and introduces the importance of interdisciplinary learning and approaches at the undergraduate level.\(^3\)

Graduating seniors in EPP regularly rate the following ABET student outcomes significantly higher than non-EPP majors on exit surveys:

(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, and sustainability (Note: not manufacturability)
(d) an ability to function on multidisciplinary teams
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a
global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues

In their 1974 article introducing the EPP program, Robert Dunlap and Gordon Lewis, who both
co-chaired the department at its inception, concluded with four reasons for being optimistic about
the success of the EPP program. A reflection on their reasons for optimism 40 years later.

1. It is an undergraduate program - start from the beginning to develop skills in both social and
engineering analysis, rather than in grad school where disciplinary constraints have been
developed.

Prospective undergraduates are excited about a program where they can tap into their interests
outside of science and math, and have not yet been exposed to the silos of engineering education.
Students in the program are happy to have a place where their engineering discipline meets the
real world. The graduate program in EPP started about four years after the undergraduate
program. It is now highly regarded as one of the best in this interdisciplinary domain. The
accepted doctoral students often have traditional engineering backgrounds and careers, but have
recognized their limitations being only trained as engineers, and are seeking the doctoral degree
in EPP to expand their knowledge in the social science aspects.

2. The program is a dual track - not giving a veneer of the other discipline to students.
   Graduates are capable of doing professional analysis in both domains.

This has been a mainstay of the program. Students are expected to complete courses in both
engineering and social science areas. The program emphasizes that our graduates are top-notch
engineers, but more than that - engineers with a difference, with an additional skill set to help
them manage and address today’s complex problems.

3. The program provides integration of the dual education tracks - experience on real problems,
   an internship, and project courses on actual problems with both social and technological
   components.

While we no longer have an internship requirement, the technology-policy electives and the EPP
Projects courses continue to emphasize current issues at the interface of technology and society.
Alumni report that the EPP Projects course was a critical learning experience for their current
position, and they were ready to take on projects on the job.

4. The program exists in a university in which cooperation between engineers and social
   scientists is more than a mythical fancy.

This cooperation and interdisciplinary focus has only grown at Carnegie Mellon University over
the past forty years. It is critical to this program’s success.
