# Defining the Knowledge and Skills that Enable Engineers to Participate in Public Policy

**J. Mendoza-Garcia, Purdue University and Pontificia Universidad Javeriana**

He is a Ph.D. student and a Research Assistant in the School of Engineering Education at Purdue University. His advisor is Demetra Evangelou. He worked for industry for seven years and then became an academic. He has been a professor of the Department of Systems Engineering at Pontificia Universidad Javeriana in Bogotá, Colombia, since 2005. He is interested in research about learning engineering complementary knowledge like systems thinking and public policy. He is also interested in topics related to learning communities, social awareness, and motivation in engineering. He finished his bachelor's degree at Universidad Nacional de Colombia and his magister (honored degree) at Universidad de los Andes. Both degrees were in systems engineering and computing and both universities are located in Bogotá, Colombia. Email: mendozag@purdue.edu.

**Ms. Ida B. Ngambeki, Purdue University, West Lafayette**

Ida Ngambeki is a doctoral candidate at the School of Engineering Education at Purdue University. Her research interests include vocational choice in engineering, human-artifact interaction, and engineering and public policy.

**Lamis J. Behbehani, Purdue University**

Lamis J. Behbehani is a Ph.D. candidate in ecological sciences and the Engineering Interdisciplinary program, Purdue University.

**Dr. Demetra Evangelou, Purdue University, West Lafayette**

Demetra Evangelou, Ph.D., is an Assistant Professor in the School of Engineering Education at Purdue University. She obtained her B.A. in psychology from Northeastern Illinois University, and a M.Ed. and Ph.D. in education from University of Illinois, Urbana-Champaign. She is a member of Sigma Xi Science Honor Society. Evangelou was awarded an NSF CAREER grant in 2009 and a Presidential Early Career Award for Scientists and Engineers (PECASE) in 2011. Evangelou's current research focuses on engineering thinking, developmental factors in engineering pedagogy, technological literacy, and human-artifact interactions.

**Prof. P. Suresh C. Rao, Purdue University, West Lafayette**

Suresh Rao is the Rieth Distinguished Professor of ecological engineering in the School of Civil Engineering at Purdue University. Prior to coming to Purdue 13 years ago, Rao was on the faculty for 25 years at the University of Florida. His research and educational interest span a broad spectrum of trans-disciplinary themes at the intersection of how human societies alter natural landscapes, and how multitude of ecological adverse impacts cascade through complex coupled systems. He teaches multiple courses with emphasis on application of sustainability and resilience concepts to better manage complex systems. He has worked on translation of research findings to development of practical solutions, and to inform policy development.

**Dr. Monica Farmer Cox, Purdue University, West Lafayette**

# Defining the knowledge and skills that enable engineers to participate in public policy


## Abstract

The role of engineers in public policy can be seen as a twofold endeavor: (1) to help create public policy related to the utilization of technology to solve public problems as well as monitor and assure compliance with such policies; and (2) to use engineering knowledge to assist in the construction of policy directives to help solve social problems. The policy, engineering, and engineering education communities, through speeches, statements, and reports, have agreed that it is important that engineers participate fully in the policymaking process. Therefore, it is crucial that students increase their understanding of different public policy issues, and understand the policy creation and evaluation process. A few courses and even fewer programs of study exist that address this need. However, there is little empirical understanding of the knowledge and skills engineering students must obtain in order to be able to participate effectively in the creation and evaluation of Public Policy issues. This study attempts to define the skills and knowledge necessary through a literature review and interviews with experts. The first part of the paper reports the results of a literature review regarding the skills and knowledge necessary for engineers to participate effectively in public policy creation, implementation and analysis. The second part of the paper reports the views of five experts with different backgrounds in the field of engineering and public policy. The results from the literature review, providing a theoretical perspective, and interviews with experts, providing a more practical perspective, were combined to propose a profile of the skills and knowledge students of engineering might need to learn to be able to participate effectively in public policy. Knowledge of the workings of government, an understanding of the policy making process, the ability to communicate beyond disciplinary boundaries, and an understanding of the diverse interactions of technology and society emerged as the most important skills and knowledge these experts felt students should have. These results are expected to add to the academic discussion in this area and be useful to the growing field of Engineering and Public Policy to guide colleges and universities as they build, expand, and improve their programs of study.


## Introduction

In 2004, the National Academy of Engineering (NAE) published a document titled "The Engineer of 2020: Visions of engineering in the New Century"[1]. One of the claims made by the authors of this report was that engineers must "get more involvement in the setting of public policy and participation in the civic arena" because "technology …[has become]… increasingly ingrained into every facet of our lives"[1]. Although programs in engineering and public policy started more than twenty years ago in well-known Universities like Carnegie Melon (1976) and Maryland University (1981) [2], and the need for engineers that know about public policy was manifested by entities like IEEE [3]; there is no agreement yet, in the academic community, as to what and how to teach and engage engineers with public policy. The main goal of this article is to identify the basic concepts (knowledge) and the necessary skills that will enable engineers to participate effectively in public policy. In order to achieve this goal, we divided the article in two

sections. The first one is reporting the results of a literature review, and the second one is reporting the results of the interview process.

**Literature Review**

*Methods*

This activity was focused on articles or documents related with experiences shared by the academic community when teaching public policy mainly to engineers, or on documents in which the need for engineers who get involved in public policy is expressed or in documents in which our question about the knowledge and skills that enables engineers to get involved in public policy was answered.

While doing this research, it was found that even though there are programs in some universities across The United States about technology or in engineering and public policy; the publications related to how this topic should be or is taught or the learning goals that must be pursued, or the knowledge and skills that must be developed, or the crucial topics to take into account when teaching public policy, although searched, were not found. Likewise the syllabuses of related courses that are taught in those universities were nonpublic in most of the cases. On the other hand, some isolated experiences related with teaching public policy to engineers that were found (nineteen), but most of them have been published in the memories of the ASEE conferences after 2006 (nine out of nineteen). The documents were categorized according to the three categories that are mentioned in the previous paragraph and are found in the table 1.

| Related content of the publication | Academics | Professional Associations |
|---|---|---|
| Sharing experiences | Myers and Stuart[4], Harter and Libros [5], Grose [6], Sicker and lookabaugh[7], Mc Devitt, Jansson, Vizz, Riddle and Bathia [8], Tull and Jones[9], Rusell, Marshall and Tramba[10], Isaacs, Barry and Bosso[11], Green and Emison[12], Dunn[13], Devon and Haight[14], Hyman[15], Yeigh and Yeigh[16], Ross and Karis[17], Olds and Wiley[18], Wiesner[19], | |
| Need of Engineers to talk about public policy | | Andrews and Clint [19], Casazza[3] |
| Knowledge and skills | Myers[20] | |

The next step in this literature review was focus on finding what the authors said about the development of possible skills and knowledge that engineers should develop in order to succeed in public policy. Most of the times, both categories were not mentioned in the text but were inferred by the authors by analyzing the language that was used when describing the experience or when claiming for involvement of engineers in public policy. To facilitate the analysis, a concept map was created. One example is shown in figure

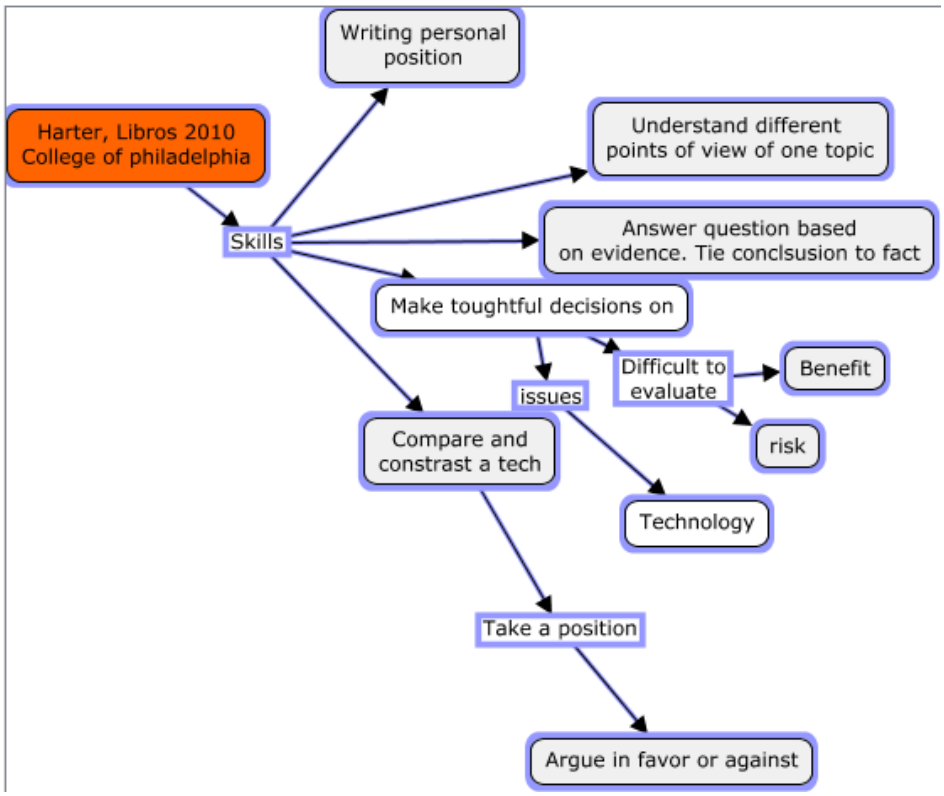


**Figure 1 - Skills identified in the article of Harter and Libros from the College of Philadelphia**

## Results from the literature review: Basic concepts that engineers should know about Public Policy (Knowledge)

The following concepts related with public policy emerged repeatedly from the literature related with teaching public policy to engineers: the definition of public policy, the role of engineers in public policy from a historical point of view, the interaction between engineering and public policy, the source from which public policy emerges, and the policy making process and the need for engineers to know how to write public policy. Because of the nature of the problem, the type of literature review done for the project was thematic. In this review, the major ideas of different authors who have written about general curricular design, curricular design in public policy for STEM programs, or that have published their course curriculums in public policy and their se students are categorized under the umbrella of STEM, were investigated and summarized[21].

### *Definition of Public Policy*

In order to effectively engage in public policy, engineers must understand what public policy is. Tull & Jones [9] established that public policy is the "funding, procurement, and/or regulation that the government provides". Myers [20] includes in the definition "decisions", "commitments" and "actions". In addition, it includes not only the government but also the interpretation of the government's positions of authority interpreted by "various stakeholders" [20] . Myers also adds

that a public policy "affect[s] the daily lives of the government citizens"[20], "our lives including, but not limited to, federal, state and local governments. Public universities, its utilities, and NGOs may also be included."[14].

*History and role of engineers in Public Policy*

It is also helpful for engineering students to be aware of the history of engineers in public policy so they can understand how the current role of engineers in public policy has developed. For example Grose [6] explores the possible reasons that explained why American engineers are not as involved in public policy as in some other nations. According to Grose [6], this fact has a historical basis namely an inherent association that existed between local business and early land-grant colleges that made American engineers always "tightly aligned with industry" [6] and because of that, engineers "haven't been encouraged to become public servants" [6]. This is not the case in many other nations for example in France, in which engineering schools were devoted to supplying the government demands for engineers [22], engineers have "historically constituted the French state"[23]. Likewise, in China, "many engineers have held powerful positions in the upper ranks of … [its]… ruling communist party" [23].

*The role of policy in technological development*

Another topic that engineering students must learn is how public policy affects their technical field. One way to gain that knowledge is by studying the legislation about topics related to different engineering disciplines.[1]

The necessity for engineers to know about regulations could be inferred from Isaac et al's argument that: "[regulations] promote the advancement of research and development, promote more timely commercialization of products, protect the public from possible negative effects of these technologies and their use, and, in the process, be responsive to public concerns regarding technology"[11].

Cassaza [3], in the same way, claimed that engineering students should understand the role of regulation as a "substitute of market forces" [3] and that engineers could also be involved in the "process of establishing tariffs" [3] in the market. As a consequence, one could argue that if students know about regulations, they would discover how those regulations affect their discipline. Once they are able to identify those regulations, they can identify opportunities for developing products within those regulations that, "protect the public from possible negative effects of … technologies" [11]. The regulations, or the laws, are also the warrants that validate the claims that an engineer could state when creating solutions [17].

*The source from which Public Policy emerges*

Students must also be aware of who shapes the public policy. In order to participate in policymaking, students need to understand the various stakeholders in the policy process. Casazza claims that there is a "bias" against engineers at "Federal hearings in Washington" [3] because of "their poor understanding of the working of the workings of government " [3]. Green

and Emison [12], in the same way, proposed the following roles from government as crucial to be understood in "setting public policy": "Legislatures (Legislative staff), lobbyist, bureaucracy, courts, interest groups and chief executives"[12]. Myers and Stuart [4] also argue that students should learn how a law is enacted and how various actors affect that process. Myers argues that groups and individuals exercise "influence in the forms of money, prestige, information, media attention, leadership, and political management skills to sway senior legislators to its agenda" [20].

*The policy making process*

One additional concept that engineers should address is the policy-making process. According to Hira & Bailey [24] not understanding the policy making process makes individuals "see policymaking as an irrational process driven solely by ignorance and political influence" [6]. This discourages individuals from getting involved in the policymaking process. Understanding how to use relationships and influence to affect policy is also important for engineers trying to influence policy related to engineering.

**Results from the literature review: Skills to be able to participate in Public Policy**

*Communication*

Communication is a critical skill that engineers must develop in order to succeed in public policy. One of the claims Cassaza [3] made was that "engineers must develop significant communication skills" as one of the ways to decrease a "bias" [3] that, according to him, existed against engineers in the United States government. Likewise, Dunn [13], Tull and Jones [9] proposed courses in public policy for engineers in which the learning outcomes were related explicitly to the development of communication skills. Dunn [13] argued that author's students should "communicate project results effectively" [13]. Tull and Jones [9], similarly, argued that students should develop "verbal, written, graphical ... skills with special emphasis on the verbal communication of technical information"[9]. In other courses, like the initiatives presented by Devon and Haight [14], by Harter and Libros [5], by Yeigh and Yeigh [16] or by Myers and Stuart [4], communication is not explicit as a learning outcome, but to succeed in the courses, students were asked to do assignments in which they had to use effectively their written and verbal skills.

Some of the assignments that students were asked to do were "oral presentations of … [project] … results" [14], a written report with a critical analysis [14] and tasks focus on the development of skills while working independently out of class [4]. Other strategies proposed were the writing of "position papers"[5] or the engagement of students in public policy debates [16]. However, one strong concern about engineers' communication skills is not their ability to communicate technical knowledge but their ability to communicate that knowledge in a way that could be understood by people from other technical disciplines or even more challenging, by non-technical people. Teaching engineering students merely to learn universal expected procedures …[that are appropriate only in their own field],… will provide them with inadequate preparation for the multidisciplinary arena of public policy [17]. Cassaza reinforced this idea: [Engineers]… "must understand that there are different audiences for which different techniques must be used" [3]. Likewise, Dunn [13] made their students present their project to the external public, the Chicago

Department of the Environment and to the Environmental Protection Agency (EPA), a very different audience to engineers.

Finally, a further skill related with communication, is the ability to express opinions, relay facts, and articulate arguments clearly and concisely in writing. This skill is "substantially different [from] writing laboratory or design project reports" [4]. This knowledge can be taught in different ways such as writing a letter to public officials[20] or how to write a public policy for "targeted audiences"' [4]. The work from Ross and Karis [17], supports this claim: The importance of communicating effectively in sites ... labeled as "non-congruent sites of discourse," that is, sites in which they will need to interact and communicate with members of discourse communities whose file-dependent rules and procedures are different from their own.

*Contrast and Compare multiple attributes to make decisions*

Engineers, in order to be ready for public policy, must develop the ability to weigh different attributes in order to contrast and compare them before making a decision. Tull and Jones [9] justify this skill with the definition of public policy since it is "the art of the government in terms of selecting alternative courses of action" [9]. Myers [20] also shows that this skill is needed because public policy can be shaped by "competing groups, seeking shares of government resources" [20]. According to Myers, in the process of public policy, a public policy maker will be lobbied by members of competing groups in order to promote the inclusion in the agenda of issues that benefit the group they represent. Tull and Jones [9] also support this skill while explaining the role that engineers can play as public policy analysts. According to them, the policy analysts "formulate, implement, and evaluate public policy … [using] … cost-benefit analysis, and risk analysis to analyze public policy alternatives" [9]. Likewise, Cassaza [3] and Harter and Libros[5] supports the notion that engineers must be able to evaluate different alternatives. When communicating those alternatives to the public policy decision makers, they need to be able to explain "what alternatives were considered, why were those chosen, what assumptions were made, and what the uncertainties were" [3]. In the same way, students who were taught by Grose [6], had to complete a project in which "the key … was … [the] … process called multi-attribute decision making, which requires weighing several factors [in which the possible outcomes were ranked]" [6]. Rusell et al [10], reinforces this idea by stating that well-grounded decisions required the understanding of different issues like "technological capabilities, limitations, costs, and collateral impacts" [10]. Myers and Stuart [4] added economics, risk and environmental issues to the attributes that can be contemplated in decision making.

*Interdisciplinary work*

The final skill that is going to be presented as a result of this literature review is related to the ability to appreciate and work with people from other disciplines. This skill is relevant not only for public policy but for preparing engineering students to interact in all environments in which they might find themselves working as professionals [10]. The way in which every profession communicates and works is different. It is critical that engineering students acknowledge that the values and manner of interaction of each profession with technology and society are different [125].

If engineers do not take a more active role in the setting of public policy, they will be left to work within the policies set by others who may lack adequate technical skills and they will be remiss in their duties as citizens to foster good policy. If the policy setters do not develop a greater appreciation of the technological issues involved they will develop and implement policies that are less than optimal [12].

**Interviews with five experts**

*Method*

Data for the second part of this study were collected through interviews with experts with different backgrounds in engineering and public policy. Since the IRB for this research said that the identities of the experts would be kept secret, a brief description of their background is provided in the table that follows:

| | |
|---|---|
| Expert 1 | This engineer is currently a professor in a University in the north east of The United States. He has been a congressional fellowship representing one professional association and was part of a committee on science and technology. |
| Expert 2 | A professor from a University in the South West of the United States. This expert advises a Governing council of democracy and science and work in a center which studies the relationship between society, technology and science. |
| Expert 3 | A Professor whose professional experience has been in a University. Works in a department that is focus on teaching public policy to engineers. Currently this expert is head of an undergraduate engineering program. |
| Expert 4 | This engineer worked as a senator adviser for one State, has done research for a federal laboratory and has been the president of the ram of one professional association that is focus on Public Policy. |
| Expert 5 | This expert is currently a professor of science and society in a University located in the south West of the United States. The expert has worked as consultant in the house of representatives, has coordinated committees of science and policy initiatives, have develop programs in Public Policy for professional societies and has been director of science, policy and outcomes in different governmental and educational institutions. |

These experts, although currently most of them are professors in different universities, their backgrounds are broad and represent opinions from technology and policy professors, individuals working for government agencies involved in policy creation and implementation, and individuals working for private organizations related to policy. Experts were selected by the researchers specifically to represent these wide range of backgrounds, therefore while all the experts chosen had some relation to engineering and public policy, they were not all trained as engineers. Experts were contacted via email by the researchers and asked to participate in the project. Interviews were then completed by phone using an interview protocol developed by the researchers. The interviews were transcribed and analyzed trying to identify common themes or categories related with the skills and knowledge that engineering students should develop to get involved in Public Policy. Interviews are still ongoing, but the results from five participants are reported here.

**Results from the interviews**

Several themes emerged from the experts' opinions of what was essential for engineering students to know to engage effectively in public policy discussions. Many of these themes were similar to the factors that emerged from the literature. These themes include an understanding of:

- The policy creation process [Experts 1,4,5]
- How the government is structured and how it works [Experts 1, 3, 5]
- How policy affects the development and utilization of engineered artifacts for example through funding and patents [Experts 2,3, 5]
- Decision making processes [Experts 3,4,5]
- How to communicate across disciplines and to non-technical audiences [Experts 1,2,3,4]
- How the executive branches of the government are related and how they are involved in public policy [Experts 1, 4]
- The various roles that engineers currently play in the policy process [Experts 2, 5]
- The inherently political nature of technology [Experts 2,5]
- How technology influences national security and foreign policy [Experts 1, 4]
- The diversity of policy vehicles that affect technology [Experts 4, 5]
- The scales at which policies exist i.e. local, regional, national, international, and how policy differs across these scales [Experts 2, 4]
- The responsibility of engineers for the consequences of technology and the ethics related to technology creation and use [Experts 2, 5]
- The economic considerations that affect policy decisions [Experts 3, 4]
- How to craft convincing and concise arguments [Experts 1, 3]

In the same way, the following topics didn't have coincidences with other experts but might result relevant when matching these five with other interviews:

- The role of policy in shaping access to technology [Expert 2]
- The role of technology in shaping society [Expert 5]
- Basic policy analysis tools [Expert 3]
- History of technology [Expert 5]

Discussion

All the experts felt students should know what public policy is. However, when asked to define public policy, all the experts had difficulty to find the words that narrows the concept. Based on their various descriptions, the following definition of public policy was synthesized: Public policy is composed of formal and informal regulations, standards or laws that affect everyone in the general public. They are promulgated to achieve publicly desired goals. Some areas in which those goals are manifested are economy, welfare of the citizens, etc. public policy can be national or international. Experts also thought that it was important for engineering students to realize the pervasiveness of policy. Many engineering students do not consider that any development, dispersal, and use of technology are governed by and have implications for policy simply by existing. Recognition of the far reaching impact that policy has on technology would motivate more engineers to become involved in the policy process.

Experts 2 and 5 also felt that engineering students needed to go beyond surface understandings of the relationship between engineering and policy and consider how technology itself was inherently political and what that meant for society and for engineers designing and creating artifacts. These experts however, acknowledged that engineering students were likely to have difficulty engaging in critical discourse of this nature since it is far outside what is considered traditional engineering knowledge.

Another major theme that emerged from the interviews was that students needed to understand both the negative and positive aspects of technology and how both of these could emerge as unintended consequences of both technology and policy use. The current nature of engineering education generally encourages students to assess the success of their solutions to problems on the basis of a narrow set of usually technical predefined goals. Other possible impacts of these solutions or the effect of these solutions on actors other than the client are generally not considered. Therefore engineering students carry this mentality into the workforce, along with the notion that their role is simply to solve technical problems without any consideration or assumption of responsibility for the context and impact of these technical solutions. This notion of the role of engineers was discussed by several of the experts. The role of the engineer in the policy process can be seen as that of a technical expert acting in an advisory capacity, or as that of an advocate for a particular position. While these two roles were both recognized as important, they were also seen as being in opposition to each other. All of the experts felt that the former was the primary function of an engineer, however, most also argued that having more engineers take on the role of advocate could result in more decisions being made based the best opinion of experts rather than reactionary politics.

An additional theme that experts 1, 3, and 5 expressed was an understanding of how government functions. As one expert expressed very few students knew answers to questions like "how many branches in the government there are, how many senators are in the US senate and how are they elected, how old you should be to be a senator or representative". Experts 1 and 4 also claimed that engineers should know about how the executive departments of government work (e.g. NASA, FBI, the department of education), since those are the ones who implements or oversee the implementation of the laws that are created by government, especially those directly related to engineering.

The role of technology in society was also a common theme among the experts 2, 3 and 5. Beyond everyday convenience engineering students need to understand how technology fits in society and how it can be used for diverse purposes. This idea could be connected with what Expert 5 argued when asking for knowledge of the history of technology since it could shows how "governments around the world have attempted to use technology as a strategy for economic growth and improvement of the quality of life."

Finally, all the experts agreed that the most important skill engineering students needed to learn was communication which incidentally was the strongest common topic in the literature review as well. The ability to communicate technical knowledge was not the main concern, in the experts' opinion the main concern was the ability to communicate technical knowledge in a way that can be understood by people from other technical disciplines or even more challenging, by non-technical people without causing misunderstanding or misrepresenting the essence of the

communication. In the same way, three of them agreed to mention the relevance of being able to weigh different attributes (technical and non-technical) before making a decision.

## Conclusion

An increase in engineering students' knowledge of public policy and the active participation of engineers in public policy has been repeatedly recognized by leaders in both the engineering and political spheres as very important. However, there is little empirical evidence regarding how engineering students should be exposed to public policy or how they should be taught about it. Since one of the first steps in defining a curriculum is related with defining the knowledge and skills that it will pursue, this study is just one first step in this curriculum building process, which according with the model of understand by design proposed by Wiggings and McTighe, is devoted to "identify the desired results"[25]. To achieve this goal, a literature review and interviews with five experts in the field of public policy were conducted. The results of matching what is required, expressed by people who belonged to professional associations, how the topic has been taught to engineers and what experts think about, are the most relevant contribution of this work to the body of knowledge of curriculum development in Public Policy for engineers. Knowledge of the workings of government, an understanding of the policy making process, the abilities to communicate beyond disciplinary boundaries and to being able to weigh technical and non-technical issues in order to make decisions, and an understanding of the diverse interactions of technology and society emerged as the most important skills and knowledge that students should have. These results are not definitive and major researches can be conducted. However, it is expected that this work contributes to the academic discussion in this area and be useful to the growing field of Engineering and Public Policy to guide colleges and universities as they build, expand, and improve their programs of study. Future work will include the completion of this study with interviews from approximately twenty experts regarding the necessary knowledge and skills along with how these might effectively be taught eventually culminating in the development of an evidence based curriculum designed to prepare engineering students for participation in public policy and policy related careers.

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