

Public Leadership Framework: Studying Approaches to Diversify Engineering Education

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Abstract—Despite the recent interest in diversifying engineering education there has been very little analysis regarding the nature of interventions needed to refashion engineering education. This article proposes a preliminary framework referred to here as the Public Leadership Framework (PLF) to examine efforts to diversify engineering education. By comparing three highly regarded programs, the PLF is used here to reveal not just their topical differences but also the differences in their orientations and the nature of engagement with society.

Index Terms—leadership, engineering education, society, and social competence.

I. INTRODUCTION

Educators, policy makers, and engineering firms are increasingly interested in technical personnel who excel not only in technical problem solving but also have the understanding and skills to operate within a complex, fast-changing social, political and cultural environment. I refer to this ability as public leadership. The interest in public leadership has translated into many innovative ventures that seek to diversify engineering education not only to better include the study of society and environment within the curriculum but also to groom engineers to be leaders and change agents. However, much of this interest has been limited to a topical engagement whereby any social component is considered sufficient to accomplish the purpose of diversifying curriculum. Such an approach has camouflaged the depth of engagement required to foster positive change in engineers. Speaking to a largely academic audience, this paper proposes the Public Leadership Framework (PLF) for Engineering Education as a framework to study and categorize different innovative.

The Public Leadership Framework outlined in this paper has three components – topic, philosophy, and praxis. First, the paper tries to categorize different educational ventures that engage with public issues along three topical streams - engineering and society, engineering and policy, and engineering and sustainability. Each of these topical streams gives students the ability to understand and intervene in the wider world within which engineering solutions are located. Second, the paper examines the philosophical underpinnings of different approaches to public leadership – what are the aims of the venture, what are the expectations from this course of study for the nature of leadership that is created? Third, the paper understands the nature of praxis that is associated with the study of public issues through interventions such as internship, case study analysis and design. This framework is used to compare three recent efforts that have tried to instill a sense of public responsibility and leadership among engineering stu-

dents. The programs compared are Department of Engineering and Public Policy at Carnegie Mellon University, USA, Department of Science and Technology Studies, Rensselaer Polytechnic Institute, USA and the Technology Dynamics and Sustainable Development section at Delft University of Technology, The Netherlands. These three programmatic efforts were chosen because they not only possess very different attributes from each other but also because they are pioneers in diversifying engineering education.

The next section of the paper will provide a partial review of the rationale behind diversifying engineering education. The following section will then introduce the Public Leadership Framework. After introducing the three programs, the succeeding section of the paper will utilize the Public Leadership Framework to compare these three programs. This comparison will form the basis for drawing some general conclusions about the nature of social engagement that should be fostered in the engineering curriculum.

II. DIVERSIFYING ENGINEERING EDUCATION

Many in society now realize that we no longer live in a world of rigid compartments, insulated worldviews and concrete certainties. Such a perspective was quite widely prevalent for much of the twentieth century. I propose that as a result of at least three factors from the close of the twentieth century to the first decade of the twenty-first, this view has progressively lost much of its solidity. A primary reason has most certainly been the dramatic rise of global interconnections in multiple domains and through multiple modes. Collectively referred to as globalization, one increasingly lives in a world marked by large-scale movement of people, finances, information, and goods and services. These processes have engendered fundamental changes in the workplace through a transformation in domains of transportation and logistics, business and finance, global regulations, and education. A second related factor is the tremendous complexity and strength that social, cultural and political issues have acquired in the contemporary world. For example, issues of cultural identity and language are surprisingly prevalent in our globalizing world. This has heightened the need for businesses and professions to hold social responsibility and sensitivity paramount in their operations. A final factor that has contributed to a changed worldview has been a series of environmental crises such as the ozone hole, deforestation and global biodiversity, poverty and ecological degradation, and climate change that have catalyzed an awareness of “our common future” [1].

In response, engineering education around the world is going through a process of flux as it seeks to incorporate

different skills, competencies and knowledge into the education process that address this altered social and public context. The expectation is that engineering students graduating with a wider basket of social, humanistic, organizational and entrepreneurial skills will have the capacity to better engage with the changing challenges in their workplace. This is a notable change from the traditional notion of engineering education dominated by technical courses, and complemented by a casual exposure to social sciences and humanities [2]. Beder has suggested that different national bodies that monitor engineering education have felt the need to “foster a broadened outlook” as a means of “raising the status of engineering [in society] and the employability of engineers” [3]. They have gone as far as to suggest a fundamental change in the culture of engineering education. A “complete engineer” according to this new understanding is an engineer with sophisticated and practical knowledge in technology and society with specific competencies such as professional knowledge and skills; science, technology and society abilities; knowledge and skill regarding organization and management; and communicative and social skills [4]. While some have argued that what is required is a ‘global engineer’ with an engineering training that will equip them with superior communication skills, facility for multidisciplinary teamwork, well-developed social responsibility and ethics, and an ability for systems thinking and complexity [5], others have maintained that such broader skills can be gained by requiring engineering students to forge partnerships with local community groups [6, 7].

The impulse to diversify engineering training has translated into several ventures that seek to introduce innovations into curriculum. While these programmatic innovations reflect the interests and skill sets of faculty members who teach the concerned courses, or administer the programs, there has been very little research that attempts to discern how this engagement is being fashioned and what are its implications for engineering curriculum. This paper proposes a framework to compare the scope and reach of different curriculum innovations to diversify engineering education.

III. PUBLIC LEADERSHIP FRAMEWORK

The framework proposed in this paper attempts to categorize the scope and degree of interest in the ‘public’ fostered through programmatic innovation. An interest in the ‘public’ is understood here as a quality that motivates students to think of society in a collective sense that is more encompassing than a narrow private sense articulated by an individual, company, corporation or non-profit group. This paper proposes the Public Leadership Framework as a framework to study and categorize ventures that seek to inculcate an interest in the ‘public’.

The Public Leadership Framework (PLF) outlined in this paper has three components – *topic*, *philosophy*, and *praxis* (see Figure 1). The topic component tries to categorize different ventures according to the nature of intervention with public issues. The topic component of the framework thus highlights the domain within which engineers are trained to demonstrate leadership in public affairs. I understand the domain of intervention through three streams – engineering and society, engineering and policy, and engineering and sustainability. The Engineering and Society stream concerns a wide spectrum of issues that includes such issues as equity, gender, cross-cultural

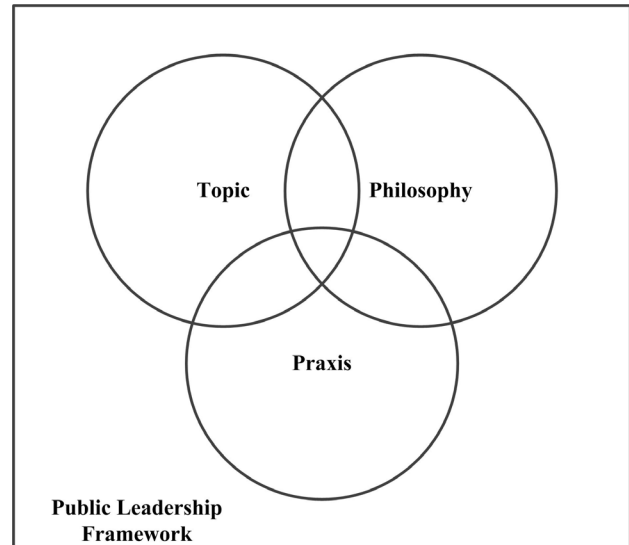


Figure 1. Public Leadership Framework for Engineering Education

communication, globalization, international service, and community engagement. The Engineering and Policy stream focuses on giving engineers the skills to influence policy formulation and implementation by governments [8]. The Engineering and Sustainability stream overlaps with the other two streams significantly but is distinct in its concern for the social, economic and environmental sustainability of technological ventures. The topical focus also concerns the nature of disciplinary engagement attempted between engineering disciplines and with those outside. Different programmatic interventions attempt to nurture the integration of cross-disciplinary material differently. This could range from a dual degree program to a minor speciality.

The philosophy component of the PLF outlines the philosophical underpinnings of the different approaches to public leadership. This is understood here as the rationale for the development of public leadership and skills associated with the curricular innovation. This component of the framework investigates the nature of “complete” engineers that each program tries to create and the role engineers are expected to assume to further public interest. The praxis component of the framework seeks to understand the nature of the intervention in public life that each program proposes their students make in order to achieve their topical goals and philosophical objectives. Interventions typically adopt new course streams to enrich student learning and to diversify their knowledge. However, more often, robust interventions are proposed that require students to operate within a real world setting. These include interventions such as internship, case study analysis, design or entrepreneurial plan. For example, an internship allows students to acquire the skills and understanding needed in the “real world” outside the university. A case study analysis gives students the analytical skills that are required of them in the professional arena. In the process, students gain powerful skills in conduct of research, interpretation, and communication.

IV. THREE CASES

The PLF is applied to three prominent cases of innovations in engineering education that seek to diversify the nature of training students in technical programs receive. These cases are the Department of Engineering and Public

Policy (EPP) at Carnegie Mellon University, the Department of Science and Technology Studies (STS) at Rensselaer Polytechnic Institute both in USA and the Technology Dynamics and Sustainable Development Section (TDSD) at the Delft University of Technology in The Netherlands. In each case, three components of the PLF – topic, philosophy and praxis – are utilized to understand the nature of the contribution that each program makes.

A. Engineering and Public Policy

EPP was established as an undergraduate educational program in Carnegie Mellon University designed to add dimensions and skills to engineering students to make them socially responsible engineers within the scope of their engineering fields [9]. The topical focus of the EPP program is on policy and policy analysis. But the crucial feature about this program is the deep integration it achieves between engineering curriculum and social and policy analytical skills [10] (an approach similar to [11]). This is facilitated through a double major undergraduate engineering degree in partnership with traditional engineering disciplines. Students who undertake this venture receive a joint degree in a traditional engineering field and in engineering and public policy. Such an educational marriage is achieved by a curriculum with “subject matter which is not part of traditional engineering or social science curricula but has elements of each” [10]. Within the curriculum structure integration of engineering and public policy elements is achieved through a well thought-out strategy that has two components. First, all technical and non-technical elective courses in a traditional engineering curriculum are appropriated by EPP and are shaped to meet the public policy requirements. Second, these elective courses are hived into EPP technical electives, social analysis electives, a probability and statistics course as well as two Project courses. The EPP technical electives cover policy-targeted domains such as energy systems, telecommunication policy, computer security and privacy, and management of technical innovation [9].

The leadership philosophy of the EPP program is best understood through their tagline that reads “Preparing Technical Leaders to address Policy Issues that involve Science & Technology” [12]. This statement makes clear that EPP seeks to nurture leadership qualities in technical professionals by giving them the ability to intervene in decision-making on issues with significant scientific and technical content. This suggests that the EPP does not educate “a different kind of engineer” [10], but rather an engineer with qualifications in analyzing social problems. The aim of the program is to create socially responsible engineers who operate within their respective fields, but while doing so have the expertise to inform policy choices made by governments and society. Although sequencing of courses in the curriculum is an important mode of intervention in the EPP, the ‘project course’ is the predominant praxis by which students receive the comprehensive training to apply their knowledge to a real-world problem. This course gives student the opportunity to integrate technical and social analysis components of their education in developing a better understanding of a problem suggested by a government or corporation. The project also gives students the opportunity to hone their verbal, oral and presentation skills in conveying their analysis. Technology policy project courses have covered such topics as Policy Dimensions of New Space Technologies;

Should Police use Mobile Computing; Public perception and community impacts of siting LNG terminals [9]. These projects equip students with the skills to intervene in public technical projects as experts with the required technical and social analysis base. Given the nature of the program and the nature of skill sets, EPP graduates find job placements in federal and state governments, and public policy consulting firms.

B. Science and Technology Studies

Unlike the EPP that complements the skills of engineers, the STS department at Rensselaer Polytechnic Institute seeks to create engineers who seek to address society’s needs in a thoughtful and integrated way [13]. The topical focus of the program is on society. This societal focus springs from the belief that a better appreciation for the social and cultural dimensions will allow student designers to design products that meet needs of users in sustainable and appropriate ways. This is given concrete shape through the interdisciplinary Program in Design and Innovation (known previously as the Product Design & Innovation program) [14, 15] that seeks to create an interdisciplinary product design experience that integrates the technical, the aesthetic and the social aspects. This integration of technical and social aspects is achieved with a dual degree program that combines a bachelor’s degree in a Technical field (such as Mechanical Engineering) with a bachelor’s degree in Design, Innovation and Society. The core of this program is an interdisciplinary design studio sequence that gives students working in teams the opportunity to grapple with multiple dimensions – social, environmental – of a design problem [15].

The leadership philosophy of the program is understood through its commitment to “provide leadership in solving ‘complex’ design problems [while being] the interface between different design cultures” [15]. The key element of this philosophy is the envisioned role of a designer who can communicate with and act as a bridge between different constituencies of the design process. Whereas engineering design education to a large extent has focused on the creation of utility through design [13], the interdisciplinary Program in Design and Innovation advances the predominant utilitarian perspective in design by nurturing more balanced and thoughtful practitioners. Leaders from the program will have the ability to “synthesize, engineering, social science and design professions in the creation of innovative solutions of the design challenges of the twentieth century” [15]. The critical praxis for energizing this philosophical vision is the sequence of eight interdisciplinary design studios. A student in the program takes one of these design studios in each semester of their education. Covering topics such as product development, user-centered design, design entrepreneurship these studios give students a hands-on opportunity on different applications of design practice. These innovations in design practice make graduates of the program ideally situated to fashion design enterprises, while others are highly sought as industrial and product designers in several cutting edge design and technology firms.

C. Technology Dynamics and Sustainable Development

The TDSD at the Delft University of Technology seeks to transform engineers but with the objective of making them partners with other societal stakeholders. It does so by integrating sustainability into the engineering curricula

not at an instrumental level by introducing courses but by seeking to comprehensively teach sustainability by transforming the paradigm of how technologies are developed. The Sustainable Technology Paradigm [16] forms the basis for TSD's interventions in engineering curriculum. At the heart of this paradigmatic approach are two shifts. First is the necessity to rework the understanding of the engineer's position within society by making students reflect upon it. Second is achieved by fostering broad stakeholder participation as a means to manage the process of developing technologies for a sustainable future. This is proposed through the introduction of Sustainability and Technology Dynamics course streams in the engineering curriculum [17, 18, 19]. Integrating sustainability in the engineering curriculum occurs at three levels. First, an elementary course – Technology for sustainable development – was developed for all students of the university. Second, sustainable development was intertwined with all regular courses in a way that is appropriate to the course. Third, develop the option for any graduate and undergraduate student in any department or program to graduate from the university with a specialization in sustainable development. The specialization option is the primary vehicle by which sustainability education is intertwined with engineering education in order to effect a change in the paradigm of technological development.

The key methodological praxis in sustainability education for engineers proposed through these efforts (especially the specialization option) is participatory backcasting. Backcasting is an innovative planning method for envisioning sustainability at a system level. It "is defined as first creating a desirable (sustainable) future vision or normative scenario, followed by looking back at how this desirable future could be achieved, before defining and planning follow-up activities and developing strategies leading towards that desirable future" [20]. Participatory backcasting provides the opportunity for students to start by constructing pathways to future sustainable scenarios. These pathways are then chosen through an iterative process that involves multiple stakeholders but also stresses stakeholder learning [19]. The stakeholder learning aspect is key to the success of the method. This implies that all participants realize that each actor possesses only a partial solution for a sustainable future. Such a re-orientation is nurtured through the backcasting exercise that students in this specialization are exposed to. The primary step in this exercise is developing a strategic problem orientation that understands a technical intervention as one lodged within a socio-technical system that has multiple stakeholders with their diverse interests. Envisioning a future scenario therefore requires incorporating these stakeholders integrally in technological development. The underlying leadership philosophy behind this program shifts the role of the engineer from a designer of technology based on scientific learning to a "social engineer" who is a manager and facilitator of the stakeholders for a sustainable technology future [16, 17]. As a manager of sustainable technological innovation, an engineer is one who involves and communicates to multiple social groups in the selection of pathways towards a sustainable future.

V. COMPARING THE CASES

Engineers in each of these programs, it is clear now, are trained to contribute in different ways to the public interest. A comparison of the three cases outlined above using

the three components of the Public Leadership Framework (PLF) – topical focus, philosophy and praxis – clarifies the nature of each approach. Such a comparison is especially useful in order to understand the nature of the leadership qualities that are being instilled into engineers through these curricular innovations. The object of the comparison is not to suggest that any of these interventions is in some way better or more appropriate than the other. This framework is a means of clarifying how engineering education and the role of engineers in society is being refashioned incrementally through these novel programs.

Comparing the topics of these three programs reveals that each has a distinct focus. The EPP focuses on enhancing the policy analytical skills of engineers while the STS program seeks to create engineers who think carefully about the social aspects in their work. The TSD program seeks to create awareness among engineers of the systemic transformation in technological change required for sustainable development. Although the topical focus is very different, it is the philosophy of public leadership that differentiates each of these reputed programs. The underlying philosophy of the EPP program is to enhance the skills of the engineer by including social and policy analytical skills within their basket of competencies. By doing so, they create an engineer who is an expert in analyzing social issues. It is these skills that allow the engineer to take upon a leadership role on problems that society needs to tackle collectively. Project courses and projects become vehicles to immerse students in specific policy issues. As the predominant praxis of the program these project courses provide students with the skill and opportunity to formulate expert recommendations that can lead to decisions in society's interest.

The STS program, on the other hand, works with the philosophy that engineers need to reflect carefully on the social and cultural aspects before designing an intervention. An engineer from this program demonstrates public leadership by being mindful of the social, cultural and political ramifications and then incorporating them into their work. Such a philosophy is especially appropriate given the praxis of the program is through interdisciplinary design studios. The pedagogic style of these studios creates an alternative methodology of practice in designing products for society's consumption. The third program believes that sustainable development requires an engineer to be reflexive in their actions in the public arena. (I use the term reflexive thinking or reflexive engineering as a perspective rooted in an understanding of the innovation process that is "more people focused, seeing publics as resources and partners in decision-making processes, and viewing education as a two-way process between engineers and communities" [21].) The underlying philosophy of this approach is rooted in the belief that the current unsustainability of development presents a challenge to engineers but especially to engineering education. Whereas the philosophy of the prevailing paradigm of engineering education creates engineers to be the exclusive bearers of skills to solve society's problems, the core philosophy of the TSD seeks to transform the relation between engineers and society into one of partnership. Within this paradigm of engineering education, engineering professionals see societal stakeholders as equal partners with themselves in the development of technologies. Such a shift can enhance the sustainability of technological development.

This paradigm change in engineering has roots in the well-established Dutch tradition of stakeholder involvement in managing technology through interventions such as constructive technology assessment and socio-technical integration. Participatory backcasting, the predominant praxis associated with this curricular innovation, resonates with the broad-based approach articulated in this philosophy. Participatory backcasting, as the name implies, involves multiple society stakeholders in developing scenarios for future technological change. Table I compares the three cases of engineering diversification.

TABLE I.
COMPARING EDUCATIONAL INNOVATIONS

	EPP	STS	TSDS
<i>Topic</i>	Policy	Society	Sustainable Development
<i>Philosophy</i>	Expert Engineer	Reflective Engineer	Reflexive Engineer
<i>Praxis</i>	Projects	Design Studio	Participatory Backcasting

The differing praxes of the three ventures are closely related to the topical focus and the philosophy of each of these ventures. However, a topical focus does not completely determine the choice of praxis. While it is evident that a design studio may be appropriate for enhancing social appropriateness but much less appropriate for policy analysis, at the same time, projects are appropriate praxes for not only consultative analysis that EPP seeks to foster, but also can be appropriate for either the societal or sustainable development focus of the other programs. The determining feature of these programs then is their philosophical orientations. The differing philosophical orientations are crucial in the choice of praxes. Fostering an expert engineer who can provide advice requires a praxis that will allow gathering of information about a case without intervening directly into the case. This is very different from the aims of creating a reflexive engineer who will directly become an agent of transformation. Participatory backcasting through its broad stakeholder engagement becomes a preferred mode for effecting such a transformative change in society. Identifying the choice of philosophical orientation and praxis is key to understanding the nature of the change that is being effected in engineering curriculum.

VI. CONCLUSION

From the above study two important points can be made about transformations in engineering education. First, there appears to be a trend towards diversifying engineering education. Several programmatic efforts have been launched with the intention of becoming a vehicle for this change. These interventions are broadly centered around three topics – policy, society and sustainable development. Programmatic efforts launched at Carnegie Mellon University, Rensselaer Polytechnic Institute and Delft University of Technology are well-established examples of interventions with a focus on policy, society and sustainable development respectively. A second major point that follows is that despite the push towards diversifying engineering education there has been very little thought or research into the nature of the intervention that should be made in refashioning engineering education. I chose to compare these three highly regarded programs in

order to indicate the differences in their orientations. As a preliminary study, this paper indicates that using a framework such as the public leadership framework can reveal to all stakeholders in engineering education that multiple directions are available to take the field forward. But these directions are not fully grasped by limiting our attention to a topical focus alone. From the analysis in this paper it is evident that the underlying philosophy, and praxis of the program are critical to comprehending the nature of intervention in engineering education. A program that seeks to create an expert engineer will seek to develop more analytical expertise, while a program that seeks to create an engineer who is thoughtful and reflective seeks to develop praxes that find a new balance in their practice. On the other hand, a program that seeks to make more fundamental transformations in society by producing a reflexive engineer requires a praxis that can support such a goal.

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