New Orleans JAZZED about Engineering Education

Paper ID #16973

A Principlist Approach for Thinking About the Social Impacts of Engineering

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A Principlist Approach for Framing Conversations with Diverse Stakeholders About Engineering Practice

Abstract

A recent report from the National Academies of Science and Engineering with the Institute of Medicine highlights an emerging shift in thinking about the process of technology development. The report, commissioned by the Defense Advanced Research Projects Agency, focused new attention on the conversation about social contexts and impacts of engineering, particularly the designing and implementation of new technologies. This report suggested a need for changes in the content of the conversation about social impacts of engineering to include broader issues such as social justice and respect for autonomy as well as in the diversity of participants of that conversation. These changes raise an important question for engineering educators: "How do we best prepare engineering students to participate in the changing conversation about the social context and ethical impacts of their profession?" Developing an answer requires a rethinking of paradigms and pedagogies for teaching about professional responsibilities and communication competence. In this paper we propose that the four principles of a common morality could provide a rigorous framework for engineers to engage with a diverse range of stakeholder perspectives on the social contexts and impacts of engineering. This principlist framework opens space for engineers to more richly explore the complexity of both direct and indirect social impacts resulting from their work. Thus, in this paper we argue that such a principle-based approach applied reflectively in the context of engineering design, is an important component of a response to these challenges of communication competence. The specification and balancing of the four principles that is essential to this principlist approach requires thinking together in specific contexts about the perspectives and potential social and ethical concerns of diverse stakeholders, ranging from corporations to culturally-diverse individuals, to animals and the environment. Developing an answer to the question of appropriate pedagogy certainly will involve significant dialogic interactions between engineering educators and educators in several disciplines in the humanities. While some engineering educators are focusing the emphasis of their work on these issues, the terminology, discourse communities, and educational practices associated with the topics of social impact such as autonomy and justice, for example, most often come from disciplines outside engineering and are not readily ascertainable by engineering students or even faculty members. As complex social and ethical issues are growing in emphasis in engineering contexts, engineering professionals as well struggle to frame their thinking and find effective language for necessary engagement with diverse perspectives. A principlist approach, applied through a series of case examples, could provide a framework within which engineers can responsibly and effectively communicate about the changing ethical content and with a more diverse range of participants in the conversation concerning the contextual influences and potential impacts of engineering on society.

Keywords:

Engineering ethics; Ethical reasoning; Principlism; Social Impacts; Communication Competence

Recently an important report created by the National Academies of Engineering and Science with the Institute of Medicine highlighted an emerging shift in thinking about the evaluation of social issues surrounding the process of technology development. The report entitled, *Emerging and Readily Available Technologies and National Security: A Framework for Addressing*

Ethical, Legal, and Societal Issues[1], was commissioned by the Defense Advanced Research Projects Agency (DARPA), and focused new attention on the conversation about social aspects of engineering, particularly surrounding the designing and implementation of new technologies. This refocusing involved necessary change in both the *content* of the conversation about the social impacts of engineering new technologies and in the *participants* in that conversation. Such engagement in conversations about social and ethical contextual issues is likely to "introduce excessive ambiguity and throw engineering student designers into highly unfamiliar interdisciplinary terrain"[2]. This potential for creating ambiguity and disorientation can have negative or positive effects on the engineering process depending on how skilled is the engineer at engaging with the diversity of concepts and perspectives. And because of the typical lack of communication skill some have even questioned whether engineers should be considered competent to engage independently in global or even local development work given their "widespread lack of sociotechnical perspective" and given the "dangers of not engaging effectively with those who have other forms of expertise" necessary to evaluate the social impact of engineering solutions.[3]

Thus these changes in the conversation raise an important question for engineering educators that we discuss in this paper. That question is: "How do we best prepare engineering students to effectively participate in the changing conversations about the societal and ethical aspects of their profession?" Developing an answer requires a rethinking of paradigms and pedagogies for teaching about social context and effective communication, especially with the broader range of stakeholder communities being involved with and impacted by the engineering of new and emerging technologies. In this paper we argue that a principlist approach, recently evidenced as effective in enhancing ethical reasoning in engineering[4], can also be applied to enhance the *communication competence* of engineers. We propose that the conceptual power of the four normative principles of a common morality will provide a rigorous framework for thinking about social values from multiple and diverse perspectives. We also propose that the process-based and iterative reflective reasoning of the principlist approach will provide an engaging and familiar structure for guiding engineers as they engage in dynamic conversation with diverse and complex value perspectives of stakeholders. Increasing the competence of engineers in discursive dialogue will open space for engineers to engage more fully and even more richly understand the complexity of both direct and indirect social contexts and impacts of their engineering practice.

In what follows, we give examples of the sorts of changes to content and participants that are reflected in the emerging shift in the conversation about the social and ethical issues surrounding engineering design and implementation. We then discuss challenges to communication competence in terms of the complex role of perspective-taking among various levels of ethical engagement. Next we articulate how Reflexive Principlism can serve as an effective framework for engaging engineering students in conversations with diverse stakeholder perspectives; conversations that can be challenging because of the limitations of the students' educational background, communication skills, and professional training. Having multiple diverse perspectives in the conversation is central to effective ethical and socially responsible decision-making in engineering. Using examples of possible contexts for application, we conclude that this theoretical framework for engaging students offers a solid support for building communication competencies and decision-making practices.

Changing the conversation content

The NAES report recognizes the potential for emerging technologies to "outpace the evolution of the laws that govern their use"[1] and proposes a framework for policy makers to expand the social and ethical considerations and participants in the conversations so that this outpacing might be prevented. While this report focused on several specific emerging technologies with particular application domains (e.g., "information technology, synthetic biology, and neuroscience" and "robotics, prosthetics and human enhancement, cyber weapons, and nonlethal weapons"), the framework proposed is intended to apply to any potential translational technologies, (i.e., those able to be directly implemented and have the potential to impact individuals or large numbers of people indirectly or directly). The Report defines a number of "cross-cutting themes" – or themes that intersect a diversity of stakeholders in a wide range of cases. This list includes questions of "scale, humanity, technological imperfections, unanticipated military uses, crossovers to civilian use, changing ethical standards, ELSI considerations in a classified environment, and opportunity costs" [1]. While many of these "themes" have been objects of ethical inquiry in areas other than emerging engineering technologies, their inclusion in the Report's analysis suggests a new foregrounding and broadening of their implications in engineering. Considerations of the social issues surrounding emerging technologies demand a focus not only on the costs and benefits (avoidance of harms and evidence of added value) but also on centrally important social and ethical issues of autonomy and justice. One illustrative example of the social and ethical considerations in these emerging domains of engineering design and implementation would be the challenges to autonomy that might result from the changes in personality and identity that can occur in response to therapeutic use of deep brain stimulation technology.[5] If a person's cognitive and affective functions are altered by application of this emerging technology for deep brain stimulation (e.g., for epilepsy or Parkinsonism) to a degree that changes their personality and thus potentially their sense of identity in terms of authenticity or autonomy, how would this impact their previous informed consent for the application of the technology? What would be the response to the patient "changing their mind" about accepting the treatment? And how should such social and ethical concerns impact or guide the innovative development and implementation of such an emerging technology area. A second example of a challenge to autonomy would be the "secondary technologies" in engineered devices with primary functions we readily accept in daily life (e.g., mobile phones, and automobiles). These secondary technologies might have functions (e.g., surveillance tracking of individual activities[1]) that might not be acceptable to many users but are being used without their consent or knowledge.[6,7] These additional functions engineered into commonly used technologies and devices raise important concerns about privacy, technological paternalism, as well as assignments of legal, social, and moral responsibility.

Another emerging change in the content under consideration for conversations about ethical and socially responsible engineering design and implementation is justice: particularly social justice issues as apply to technology translation and delivery (e.g., into lesser-developed communities, an approach sometimes termed humanitarian engineering or engineering for development). The social context and impact of engineering activities on a global scale are raising serious ethical and societal concerns related to paternalism, imperialism, colonialism, and other problematic and

[1] While many examples focus on undesired impacts on individual human autonomy, one might consider a much wider set of examples that would include impingements on the autonomy of particular social groups, communities, nations, or even nonhuman animals. A lengthier discussion of the nature and scope of autonomy in future work will address these possibilities.

systematic inequalities.[8,9] And as some have noted, "as long as faulty assumptions of the role of technology in 'solving' development problems persist – as might be expected among a large number of engineers and engineering students – the relevance of local context is likely to disappear when it comes to the technology design process."[10] The impacts of engineering technology development and implementation on social justice are broader still; for instance, in terms of distribution of healthcare goods. The just distribution of healthcare is a key ethical issue[11, 12]: socio-economic disparities make many healthcare options and technologies inaccessible to the worse off members of society. As biotechnological advances continue to interface with healthcare delivery and implementation, engineering activities that support those advances have both direct and indirect impacts on those questions of just distribution and access. Questions about the engineering impacts on socially just healthcare are grossly understudied, although they're received some attention as parts of broader social justice projects.[13]

The emerging relevance of questions of social context and ethical impact (e.g., respect for autonomy and social justice) in the engineering practices of design and implementation draws attention to the importance of understanding the diverse perspectives and values of the local contexts and communities in which these technologies will be engaged. Thus it is imperative that engineering educators develop effective strategies to build competence for engineers in how to communicate responsibly and effectively about these important non-technical social and ethical issues. What we are finding as educators in engineering ethics is that engineering professionals as well as students often struggle to frame their thinking and find effective language for richer communication surrounding these value-laden issues. Sometimes this is due to a lack of education about these ethical issues and questions of social context and responsibility, but often it is due to a lack of experience as participants within diverse discourse communities. Sometimes it is also a lack of common language and points of reference for the necessary conversations. And while some engineering educators are paying more attention to presenting and discussing these emerging social and ethical issues, the terms, discourse communities, and practices associated with these complex issues most often come from other scholarly disciplines and are not readily ascertainable by engineering students or at times the faculty members themselves.

Changing the conversation participants

In addition to changing the content of the conversation from a focus on laws, regulations, and avoiding harms to wider social and ethical questions of respect for autonomy, justice, and contextual impact, the NAP report points to a change in the participants in the conversations about impact. This expanded range of distributed decision-making dialogue no longer includes only those directly involved in the immediate decision. The conversation about ethical and societal context and impact is now understood to require inclusion of a widely diverse range of stakeholders, or "parties that have an interest in the project because the project may, directly or indirectly, in the short term or in the long term, have a positive or negative impact on them."[1] This is a remarkably broad definition, despite the authors' acknowledgement that "an effort to identify the *relevant* [emphasis ours] stakeholder groups is therefore an essential part of any ELSI assessment."[1] Despite questions about which stakeholder groups can be considered as relevant in a particular engineering R&D problem, the analytical framework proposed in the NAP report at least identifies the need to decidedly expand the participants in the conversation about the societal and ethical impact of technology development. There is now an awareness of the need to include others beyond directly-impacted research subjects, (including also at least those people and communities in some proximity to the subjects and testing, and also those with

insights into the potential impacts of the technology development and implementation). In addition to the perspectives and concerns of all direct and indirect stakeholders, other groups are identified as important sources of relevant insight based on their understandings related to the type and scale of impacts – especially concerning nonmaleficence themes such as "degree of harm; humanity, including what it means to be human; technological imperfections; unintended military uses; and opportunity cost, among others." Seven specific sources of these required broader insights were identified which include a broad range of new conversation participants. The insights might come from:

1. Philosophical ethical theories (e.g., consequentialism, deontology, virtue ethics) and discipline specific ethics (e.g., IT, biomedical, engineering, professional)
2. International law (e.g., laws of war, human rights law, arms control)
3. Social and behavioral sciences
4. Scientific and technological framing
5. The precautionary principle and cost/benefit analysis
6. Risk communication
7. Synthesis from across all other technologies[1]

To gather these expanded insights into the process and products of engineering design and implementation will require an expanded range of conversation participants who are intended to help identify the ethical, legal, and social issues that might not be readily apparent to those engineers officially responsible for determining need, extent, and direction of modifications or limitations (including abandonment) for the development and implementation of translational technologies. Thus the proposed framework of the NAP report strongly recommends that engineering R&D agencies should "educate and sensitize" project managers to these expanded ethical issues and "should build external expertise in ethical, legal, and societal issues to help address such issues." Further the Report recognizes that "[a] communications strategy can have an important payoff in collecting data about the reactions of different stakeholder groups...".[1] However, the formative process of socialization in engineering has not consistently included strategies for ensuring communication competence with diverse stakeholders. Thus the socialization in one's discipline and in interdisciplinary work add another layer of complexity on the expanded conversation the Report has identified.

The challenge then, given these complexities, is how to teach engineers to be able to responsibly and effectively communicate across all these varied participants with such diverse backgrounds of disciplinary expertise, professional experience, and sources of insight. Catalano has suggested, "perhaps the most important contribution we can make as educators is provide a *forum* [emphasis ours] within which students may wrestle with these issues."[8] We would expand that understanding of important contribution of engineering educators to include providing a *framework* within which students gain competence in their wrestling with such issues among themselves and even more importantly with a diverse groups of value holders. Below we discuss further the challenges and opportunities for establishing a framework and for determining what might be considered as a minimum level of competence in communication for engineers.

Challenges to communication competence

Communications scholars have defined communication competence through various conceptual lenses; indeed, some have argued that competence lacks a "coherent conceptualization and theory."[14] But, at its most general level, that competence is both "situational" and "relational"[14, 15] and is "the ability to get what you are seeking from others in a manner that maintains the relationship on terms that are acceptable to both you and the other person."[15]. The specific skills

required to attain this goal include "adaptability, ability to perform skillfully, involvement, empathy/perspective-taking, cognitive complexity, and self-monitoring."[15] From the perspective of communication about social and ethical issues, communication competence demands an ability to successfully engage in an ongoing process of interaction with and reflection on the concepts, values, and perspectives of all the participants specified in particular contexts.

The struggle to effectively frame communication and build communication competence is often due to a lack of education about ethical issues and questions of social context of engineering practice but also due to the lack of experience of engineers as participants within diverse teams of decision-makers. Sometimes it is also a lack of common experiential points of reference for the necessary conversations. And while some engineering educators are paying more attention to these emerging ethical and social contextual issues, the terms, discourse communities, and practices associated with the literature on autonomy and social justice most often come from other disciplines making it challenging to effectively engage engineering students.

If the ABET EC2000 accreditation criteria of student outcomes (3) can be considered as a baseline of competence we can identify several that could be aligned with communication competence in the context of socially and ethically responsible engineering practice. The 6 student outcomes we identify as related to communication competence are:
*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 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.*[16]

Evaluating these criteria from the perspective of Bloom's hierarchical taxonomy of basic to advanced learning[17] we can see that they cover the spectrum of levels from knowledge/remembering, to understanding/comprehending, to analyzing, synthesizing, and applying. Catalano has suggested adding an additional outcome from a more integrative model of engineering competency: "A fully integrative approach to engineering problems incorporating both reason and compassion in the development of solutions."[8]
This additional outcome reaches to the higher taxonomic level of synthesizing and introduces an additional component, compassion, to the ideal of engineering competency. Compassion is an affective attribute closely linked to the skill set of empathy and empathic perspective-taking that Hess and others have begun to investigate as a component of ethical reasoning and communicational competency in engineering.[19, 20, 21]

We have argued that perspective-taking is an important component of effective reasoning about ethically and socially responsible design[21] and further suggest that perspective-taking should be considered a component of the communication competency that all engineers should master. In fact, except in the context of international engineering students[22], the discussion and assessment of communication competency has traditionally focused on skills of oral and written presentations and reports and primarily within the engineering community context. A more recent report discusses a disparity between younger more novice engineering students and experienced professional engineers and who seem to share a wider understanding of communication competence.[23] Insufficient discussion or research has been focused on the

competency of interpersonal conversational dialogue within a context that contains multidisciplinary, multicultural, non-technical, as well as other diversity, although that discussion continues to grow.[24] We would suggest that a "fully integrative approach" to "both reason and compassion"[8] requires a level of competence in engaging with, understanding, and appreciating perspectives of the full diversity of all stakeholders in the conversations about problems as well as solutions.

If the Kohlbergian moral development theory developed by Rest is correct[2],[25] , establishing a robust understanding of the perspectives of the diverse spectrum of relevant stakeholders is essential to effective ethical decision-making. Yet communication strategies for dialogue across diverse perspectives is not yet a regular part of the training and education of most engineers. So how can we expect engineers to make good ethical decisions in their engineering practice? In an important sense, engineers make coherent ethical decisions just like other professionals or practitioners: through a process of engagement with ideas, values, and perspectives all in flux and in context. But some ethical issues that develop in engineering, like those around the social contexts and impacts of emerging technologies for example, are not directly addressed by the training most engineers receive. The skills training, technical education, and familiarity with professional codes of ethics that are supposed to guide action are insufficient for developing a rich and full understanding of these expanded social and ethical issues. In cases like these where professional views and values within engineering are insufficient to reach an ethical and socially responsible decision, the engineer has to rely on the same normative structures to which every individual has access: their own personal and societal values. Personal values are those values received from family, friends, and local communities in the formative process of socialization. Societal values are those constituted through our roles in broader peer and social groups, supporting the social cohesion through agreement about questions of right and wrong, good and bad. Yet conflicts between these normative structures – personal, societal, and professional – as well as between those personal and societal values of other stakeholders can frustrate the process of ethical and socially responsible decision-making if not resolved, especially in complex and emerging technology cases. Understanding the normative demands of socially responsible engineering must rely not only on normative roles but also on decision-making capacity. Thus a coherent and rigorous framework for engaging diverse normative values as well as for decision-making could help overcome the challenge of communication competency about and through value commitments by providing a foundation for effective communication about social and ethical issues surrounding engineering practice.

Reflexive Principlism as a Response to the Challenge of Communication Competence

In our research and recent article[4], we propose that using the approach of Reflexive Principlism might be an effective way to educate and communicate about emerging social and ethical issues in engineering design and implementation. The normative principles of common morality that underlie the Reflexive Principlism approach offer significant conceptual power as an accessible and coherent framework for thinking about social context and impact from multiple and diverse stakeholder perspectives. Iterative application of these principles in the specific context of particular engineering problems related to the social and ethical issues in design engages the

[2] We recognize significant problems with Kohlberg's theory of moral development: specifically that he privileges reasoning over affect and, in so doing, emphasizes androcentric decision-making skills. However, his model and subsequent revisions all include perspective-taking (whether rational or affective) as a necessary component.

engineer in a familiar process of decision-making built on a robust set of conceptual analysis tools.

The reasoning approach of Reflexive Principlism introduces a set of four normative principles that are shared commonly across cultures and disciplines[26, 27]: beneficence (doing good), nonmaleficence (avoiding harms), justice (equitable distribution of risks and benefits), and respect for autonomy (the right to choose to participate in the risks and benefits). These norms function at the mid-level between philosophic theory and practical codes and, thus, by giving important reference to practice and theory alike, form a common conceptual framework for ethical decision-making. Tom Beauchamp, one of the early developers and advocates of a principles-based approach in the context of U.S. bioethics, articulated the power of a mid-level approach in terms of access and shared foundation.

> Principles that could be understood with relative ease by the members of various disciplines figured prominently in the development of biomedical ethics during the 1970s and early 1980s. Principles were used primarily to present frameworks of evaluative assumptions so that they could be used, and readily understood, by people with many different forms of professional training. The distilled morality found in principles gave people a shared and serviceable group of general norms for analyzing many types of moral problems. In some respects, it could even be claimed that principles gave the embryonic field of bioethics a shared 'method' for attacking its problems, and this gave some minimal coherence and uniformity to bioethics."[27]

Beauchamp, in this passage, is noncommittal to the meta-ethical implications of principlism; that is, whether or not this set of principles is *actually* rather than merely *practically* universal. Yet his suggestion that principles – as opposed to high theory or specific case analysis – can offer multidisciplinary groups of ethical decision-makers a shared and serviceable normative model, is one that we think translates well into the growingly interdisciplinarity of engineering. The four principles can stand as a common referential points in cross cultural conversations and even across the variations of lived experiences with in engineering teams and companies.

Starting from these shared moral reference points, these principles are then specified, or made particular in context, by the details of a particular case and/or by the implications of particular moralities with their own context-rich norms. Bioethicist Tom Beauchamp describes the function of specification as a process that "adds content to abstract principles, ridding them of their indeterminateness and providing action-guiding content for the purpose of coping with complex cases."[28] Although specification is a central component to the reasoning process of principlism, it is not unique to principlism, but rather an important aspect of resolving value conflicts in any framework. The process involves narrowing the scope of applicability and placing the principle within the constraints of a specific context (e.g., what does justice mean in this case? and to whom does it have relevant impact? to what extent does it apply?). Although the principles themselves are commonly shared, these context-specific applications of moral principles may differ between stakeholder communities as well as between particular societal and (sub)cultural "customary" moralities.[29, 30] But despite these differences among particular norms, when specified in contextual applications the four mid-level norms of principlism enhance the ethical sensitivity of professionals[31, 32], and thereby facilitate communication and decision-making around diverse values. The process of specification is bounded by what political

philosopher John Rawls described as "a never-ending search for incoherence and novel situations that challenge our current moral framework."[33] Seeking coherence by this method of specification serves to constrain an otherwise directionless specification and balancing of principles. Coherence and specification together, as necessary but not sufficient conditions, are determinants of balanced ethical judgment and thus can increase competence in communication about social and ethical issues.

Finally, the process of reflection is centrally important to principlism. Seen as an ongoing process of inquiry, principles-based reasoning requires each individual agent, either working alone or together in conversation with diverse stakeholder participants, to engage in iterative cycles of reflection (see Figure 1) between the specification of the principles, their relationships to codes of ethics (both personal and professional), and related cases, and the potential outcomes they prescribe. As the engineer gains experience and confidence in this process, some of this reflection will become intuitive, or reflexive. Thus the goal is a *reflexive* not merely *reflective* principlism.

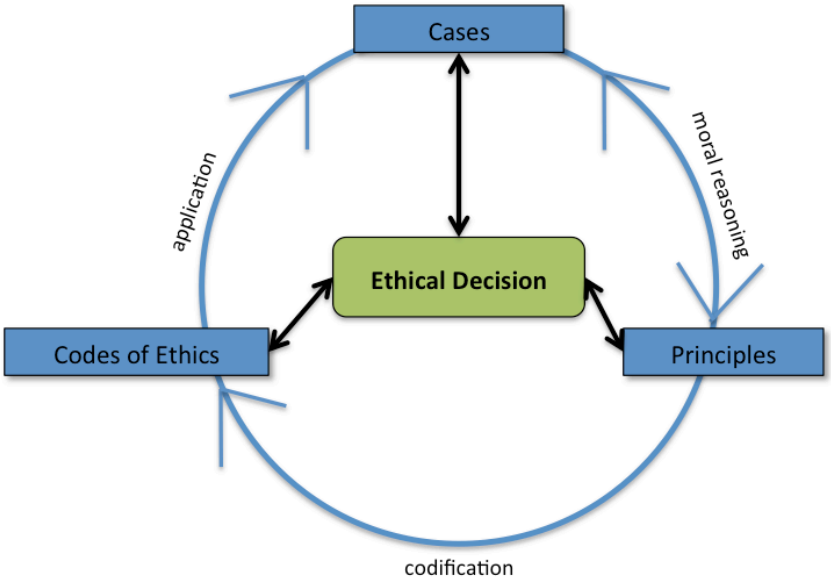

Figure 1 Illustrating the reflective interactions of Reflexive Principlism

This approach to analyzing social and ethical values and concerns in the general setting has direct applicability to engineering context of design and implementation of technology. Since the professional ethic of the engineer is integrally tied to the specifics of a particular situation, the principlist approach helps all parties to work together in conversation to more clearly define and then explain the reasons and feelings that guide judgement as necessary components of ethical reasoning in the specific engineering context. Reflexive Principlism then plays an important role as a methodology for helping engineering students communicate competently with others about to whom, in what way, and to what extent they have social and ethical obligations, especially in the context of international and cross-cultural work. For example, doing good – beneficence – will likely be specified to the particular local context and balanced out reflectively against competing needs for fairness and community autonomy. Using the four principles of common morality then as a shared point of reference will allow a broad range of participants in the conversation to engage more fully and contribute together to the critical process of specification.

The primary goal of a common morality approach like Reflexive Principlism, "to promote human flourishing by counteracting conditions that cause the quality of people's lives to worsen,"[27] aligns well with several statements of the goals and practice of the profession of

engineering (e.g., "Engineering is the creative application of scientific principles used to plan, build, direct, guide, manage, or work on systems to maintain and improve our daily lives."[27]). In addition, the principlist framework can be situated in a reflective process of communication that allows rules and potential practical guides to action to be derived and refined over time as engineering as a profession and the societies it serves continue to change. Additionally, these four categories of principles expand the scope of social and ethical issues that has been commonly addressed in engineering to include an explicit normative focus on the social contexts and impacts. These four principles draw attention to neglected areas of consideration such as respect for autonomy, particularly for marginalized or displaced individuals and communities (e.g., engineering design for illiterate or developing-world communities, or attention throughout the process of design to the needs of specific stakeholders) and social justice issues relevant to minority groups and societies in regard to the generation of advanced technologies with limited accessibility.[35,36] The spectrum of values and norms represented within the four principles delineate two normative axes that range from good to bad and from individual to society (possibly even to environment and universe) and thus frame a coherent space for social and ethical reasoning among stakeholders.

Thinking about how we might educate engineering students to best engage in conversation with diverse stakeholders about the societal contexts and potential impacts of emerging technologies, we find particularly attractive the role and conceptual power of these commonly-shared normative principles. This principlism approach, as a framework, can support an iterative, process-based reflective communication by engineers about the values, norms, and perspectives from a diverse community of participants that are critical to effective ethical decision-making. Reflexive Principlism offers a means of framing responsible and effective communication about the social impacts of engineering in the face of emerging new content and a diverse network of conversation partners.

Reflexive Principlism approach at work in engineering education

Nieusma[37] has discussed several pedagogical initiatives in which societal contextual issues can be introduced to students in their engineering training. Science and Technology Studies (STS) courses are one example where engineering students can be provided with both the conceptual knowledge of social context issues as well as the space for conversation about these complex issues. Integrating social context and ethical impact concerns directly into engineering technical and design courses is another approach. We agree that introducing students to conceptual content is key for building knowledge and a level of understanding of these issues. And we agree that reaching competency will also require some training in application of this knowledge base to specific technical and design problems, especially in the contexts of diverse perspectives. Thus we propose for the effective application of this knowledge and for gaining deeper understanding students will benefit from having a clear and cohesive framework for successful engagement in conversations with diverse perspectives. This will be true whether the diverse perspectives come from outside of the classroom or engineering workplace or from within.

We have used Reflexive Principlism with engineering students in class discussion of engineering case studies as an important stage of practice for learning to effectively engage with and resolve/balance diverse perspectives from within their own peer group. We have also used Reflexive Principlism in a more challenging stage of learning that is the direct engagement with diverse groups of community clients through service learning design projects. Below we

describe an example from each of these two learning/practice/application stages from our own experience.

A staged approach for learning to use Reflexive Principlism is likely to develop the most skill and effective application.[37] Kabo has identified a number of important pedagogical approaches for engaging students and moving them through challenging "learning thresholds" around engaging with the complex issues of social impact of engineering. These strategies include both reflective classroom discussion and engaging with actual problems facing real communities. Nieusma[37] also identifies active learning through community engagement as a successful pedagogical approach by highlighting the global engineering approach of Ingenieros sin Fronteras Colombia (ISFC, Engineers Without Borders Colombia).

> "Because contextual sensitivity is such an important part of ISFC's process, they 'actively involve the community in the identification of problems and the design of viable solutions, and often involve several local and international institutions in an effort to approach these problems from multiple perspectives'."[37]

The framework and reasoning process of Reflexive Principlism does not suggest to students that perspectives of others are always more accurate or more important than the engineering students own perspectives; rather, the move is to engage all perspectives in reflective analysis around the principles to provide an level of equanimity regarding values and specifications that can contribute to the most rich understanding of the problem and therefore likely the most effective solutions.

Engaging diverse perspectives in engineering case study analysis

We have used the framework and iterative reasoning approach of Reflexive Principlism with several engineering case studies that include issues and perspectives from multiple engineering disciplines. One case involves the students in a decision process about selecting between two systems for engineering tissue-based heart valves for pediatric applications.[39] The hypothetical case is based on real emerging technology and is set up so that the students are in the role of an engineering advisory committee to a start-up company. The company doesn't have the resources to develop and support commercialization of both prototype device systems so one must be selected. The social and ethical issues revolve around the differences in need for the heart valves (much greater for children in lesser developed and low resourced countries) and in capacity for distribution (5 systems each located in 4 western clinical settings that can only deliver 100 heart values total, but with much higher safety and success profiles versus worldwide distribution of single use systems at much lower cost so that delivery of 1000 heart valves is possible but with higher risk of failure profiles). The case study as published introduces the students to both utilitarian and individual rights approaches for reasoning about the social and ethical impact. In multiple years of using this engaging case study we have found these two theory based approaches to be limiting to the students' understanding and engagement with the diverse set of stakeholders relevant in the hypothetical problem. Since we have embedded this case in a learning module that uses Reflexive Principlism as the reasoning approach we have observed students engaging with a broader set of stakeholders (including, at least, both those directly-involved and indirectly-involved in the engineering decisions) and articulating at a more nuanced level the perspectives and specification of values and principles (e.g., social justice, respect for autonomy, non-maleficence, and beneficence) from those stakeholders' perspectives.[40]

Engaging diverse perspectives in experiential service-learning design project

Imagine sixteen eager engineering students sitting in a semi-circle paying close attention to four older men speaking about their challenges of dealing with recovery from a debilitating stroke. The goal is to find an engineering solution that could significantly improve their daily activities and quality of life. The men range in age from mid-40's to mid-60's and one of them is talking about his desire to return to his active life of hiking and other sports. One of his challenges is that his left foot doesn't lift up on stride and has become a trip hazard not to mention a bit of an embarrassment. The currently available, fixed-position foot braces, with all the metal and plastic, are heavy, stiff, sweaty, irritating, and awkward. These young and healthy students are scanning their own lived experiences trying to imagine and understand what it might be like to have such challenges as these men who are much older and come from another country and culture.

The interaction of these engineering students and the men rehabilitating from a stroke took place in Galway, Ireland in 2014. The dialogue was an early stage activity in a course in global engineering design that was developed from a partnership between our institution and Croi House, a not-for-profit community organization in Galway, Ireland, that specializes in cardiac risk reduction and stroke rehabilitation. Croi (pronounced 'cree') is Gaelic for heart and it is clear that these men who are clients of Croi House, are telling their stories from the heartfelt perspectives. Their challenges impact their entire life experience and sense of well-being and the students picked up on this. The students' questions that invited further explanation showed a depth of insight and attentiveness that were surprising to everyone, even themselves. Later reflections from the students confirmed that they were able to observe and inquire about details of the men's needs that previously they would have missed. All these students had been given instruction in Reflexive Principlism as a framework for analyzing complex societal and ethical issues in engineering design and worked through at least one case example together. About half of them had been exposed to RP in several case studies in an engineering course to develop some skill in applying this approach in a community design project. When the project required them to actually engage with community partners' perspectives they were literally quite far from their own worldview so the framework of common principles and a familiar reasoning process enabled them to more confidently and effectively engage in the conversations.[41] While this service learning example did not involve experimental design or controlled study of a positive impact of RP on communication competence, others have reported the challenges of engineering students in their communications skills with diverse stakeholders. Leydens and Lucena[42] have reported on the difficulty in communicating, particularly with listening, with stakeholders in a cultural context different from their own. Strobel et al. have looked at perspectives on empathy and care among engineering professionals and found that while present in practice these attributes lack "a coherent framework for their application and development."[19] The professional practitioners in their study identified empathy as an essential aspect of engineering that requires better communication skills for engineers to be beneficial in teamwork as well as with other stakeholders. Gilbert et al. have also reported on the challenges of engineers doing international development work and the gains in competence when the teams included social work students serving as communications managers.[43]. These are just a few further examples of engineering educators reporting on the need for enhanced communication competency of engineering students for effective social and ethical practice.

Conclusions

Increasingly, consideration of the social contexts and impacts of engineering practice forms a central element of the engineer's professional development. Engineering's potential for broad and significant impacts on societies locally and globally bring with them complex and multifaceted contextual issues that are challenging to discuss, particularly with a diversity of stakeholders. These considerations and contextual complexities require greater communication competence for engineers. In this paper we argued that a principlist approach, particularly Reflexive Principlism, might be applied to effectively frame these social and ethical issues for engineers and thus enhance their communication competence. The approach of RP was shown to be able to address the complexity of issues that come along with the broader social context and impacts of engineering today, from social justice issues to questions about individual and community autonomy to unanticipated harms and benefits. We discussed two example applications of this approach, case study analysis in the classroom and service learning practicum in a global context, and described the positive impact that the Reflexive Principlist approach had in perspective-taking and understanding of diverse social issues, by facilitating communication competence in the context of ethical decision-making and engineering design. While our arguments and examples offer initial support to our claim, future work is needed to identify, test, and apply assessment protocols that can evaluate Reflexive Principlism's effectiveness in enhancing communication competence in contexts of diverse perspectives. Several tools are currently available to measure some facets such as cultural competency[44]. moral sensitivity[32], and empathic perspective-taking[45], but more specific assessments are needed to understand the role and scope of normative principles as a framework for communication competence with diverse perspectives of stakeholders. The necessary changes in the content and participants of conversations about social and ethical contexts and impacts, driven by rapidly advancing engineering innovation, can frustrate community problem solving and team engineering efforts by overwhelming the engineers' ability to communicate with diverse communities. Building communication competence through reflective application of shared principles can help alleviate this frustration and allow engineers greater understanding of the social aspects of their work.

Acknowledgements

The authors would like to acknowledge the facilitating support of Neil Johnson and Jenni Jones from Croí Heart and Stroke Center for the interaction of the engineering students with their clients rehabilitating from a stroke described above. This special opportunity for dialogue was an important learning activity in the global engineering design course developed in partnership between our institution and Croí, a not-for-profit community organization in Galway, Ireland.

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