International Journal of Engineering Education Vol. 31, No. 1(B), pp. 414–424, 2015
Printed in Great Britain

0949-149X/91 $3.00+0.00

A Framework for the Development of Social Responsibility in Engineers*

NATHAN CANNEY and ANGELA BIELEFELDT
University of Colorado Boulder, Boulder, Colorado, USA. E-mails: nathan.canney@gmail.com, Angela.bielefeldt@colorado.edu

This paper presents the Professional Social Responsibility Development Model, which is a framework to help understand the development of personal and professional social responsibility in engineers. Social responsibility is seen as a foundational disposition that informs how engineers relate to many professional skills valued in engineering including ethics and the impacts of engineering on society. This framework is rooted in the Ethic of Care philosophy, and uses three realms to describe the development of social responsibility: the development of personal social awareness, the development of professional skills and how they relate to social considerations, and the connection between personal and professional views of obligation or responsibility. Qualitative data from interviews with engineering students are used to exemplify development in each realm. This conceptual framework is intended as a blueprint for developing studies and assessment instruments which examine the development or identification of social responsibility in engineers or other professionals. Results from one such tool are presented to exemplify one way in which this framework could be used.

Keywords: social responsibility; ethics; Ethic of Care; professional skills; developmental framework

1. Introduction

Many of the problems that engineers are being asked to solve are becoming more and more complex, requiring cross disciplinary and cross cultural interactions, with the potential for having lasting impacts on society for many generations. History has shown, especially in global development work, that engineering solutions which are conceived and developed outside of a cultural or social understanding tend to fail [1]. Moreover, as we realize the potential for negative intergenerational effects, such as global warming, engineers with broader perspectives and skills are needed to develop and implement socially responsible solutions.

With this context in mind, engineering educators are trying to create curricula that foster the development of more holistic engineers. A holistic engineer possesses knowledge and skills beyond just technical skills (i.e. math, physics, engineering, etc.) to include professional skills such as an understanding of ethical and professional responsibility, an understanding of the broad impacts of engineering solutions, multi-disciplinary teamwork skills, and other non-technical skills [2]. In contrast to most technical skills, many professional skills are developed in students throughout their lives, in and out of the classroom, before, during, and after college. Therefore, it is critical to hold long term perspectives on the development of these attributes, while simultaneously considering how the engineering educational system can positively contribute to that development. Studying the development of social responsibility allows us to examine the underlying foundation of many professional skills. Social responsibility is seen as an obligation that an individual (or company) has to act with care and objectivity, aware of the impacts of their action on others, able to see issues from the perspectives of others, and with particular attention to disadvantaged populations [3, 4]. Beliefs of social responsibility reside in the very ethos of an individual, and influence the ways in which students relate to critical professional skills such as ethics, an understanding of societal context, and global awareness.

Many professional engineering societies have voiced the need for more holistic engineers to deal with complex social issues of the future and have called upon the educational system to train that type of engineer. In the National Academy of Engineering's report *Educating the Engineer of 2020,* they call for a reinvention of engineering education to include more interaction with community and industrial partners, more diverse teaching methods such as service-learning, and an increased focus on engineering problems in developing countries [5]. The ABET accreditation board establishes criteria for engineering programs to develop many skills, including the professional skills listed above, in their graduates [2]. The bodies of knowledge (BOK) from both the American Society of Civil Engineers (ASCE) and the American Academy of Environmental Engineers include an understanding of the societal impacts of engineering solutions and ethical and professional responsibility [6, 7]. Furthermore, the ASCE BOK2 focuses on attitudes, in addition to

* Accepted 15 July 2014.

knowledge and skills, with the understanding that "attitudes will affect how knowledge and skills are applied . . ." [6, p. 172]. Included in their list of attitudes that are important for professional engineers are fairness, respect, consideration of others, sensitivity, thoughtfulness, and tolerance; all attributes of social responsibility. One of New Zealand's professional organizations, Engineers for Social Responsibility, has as an objective "to encourage and support social responsibility and a humane professional ethic in the uses of technology" [8]. In Canada, the Ritual of the Calling of an Engineer charges engineering graduates to recognize the significance of their profession and the need to act ethically and with conscience in their practice [9].

A greater sense of personal and professional social responsibility is believed to help foster these skills and attitudes in students, guiding them to use their engineering abilities appropriately to address many of the complex problems that face the world today. Through the lens of Ethic of Care [10–12], social responsibility can also be used to examine issues of sustainability, environmentalism, humanitarian engineering, and professional ethics. For example, using social responsibility and Ethic of Care to examine sustainability would guide engineers to consider future generations more fully as stakeholders in the design process. Additionally, social responsibility could be a useful perspective to examine how increased attention to professional service may increase the attraction and retention of women and underrepresented minorities in engineering [13–15].

This paper presents a framework for the development of personal and professional social responsibility, called the Professional Social Responsibility Development Model (PSRDM). Other frameworks and assessment tools related to social responsibility are summarized. Additionally, Ethic of Care as the theoretical grounding for this framework is described, including how Ethic of Care informs the definition of social responsibility used for the PSRDM. Three other theoretical models which are foundational for the eight dimensions of this framework are also described. Finally, the eight dimensions relating to the three realms of the framework are described in detail to serve as a blueprint for future research studies or assessment instrument development. Samples from interviews with engineering students are provided as evidence of how individuals may speak about the development of their views with respect to each of the three realms. It is worth noting that this framework is for the development of social responsibility, not for the identification of an individual's orientation towards social responsibility, though it may form a foundation for such work.

2. Background

The term 'social responsibility' has been used in many different ways in educational studies. Studies have used it to talk about democratic values [16], civic responsibility [17], ethical and moral reasoning [18], an awareness of the social and environmental effects of engineering designs [19], and, in terms of the lack of social responsibility, issues of unprofessional behavior such as academic cheating [20]. There are several tools that have been developed to examine social responsibility through these different perspectives, or to look at elements which may contribute to social responsibility. The Personal and Social Responsibility Inventory (PSRI) has been used to assess the institutional climate which could foster the development of social responsibility in students [21]. The PSRI focuses on five dimensions of personal and social responsibility: (1) Striving for Excellence, (2) Cultivating Personal and Academic Integrity, (3) Contributing to a Larger Community, (4) Taking Seriously the Perspectives of Others, and (5) Developing Competence in Ethical and Moral Reasoning and Action. No study was found that used this tool to look specifically at engineering students. The Student Attitudes Survey focuses on student views of the roles and responsibilities of engineers in a global society, and was used to examine how curricular changes affected the development of social responsibility in civil and environmental engineering students [19]. The Community Service Attitudes Scale (CSAS) uses a framework of altruistic behavior development to examine students' propensity towards service work, which could be seen as an element contributing to social responsibility [22]. CSAS has been used to assess both engineering and non-engineering populations [23]. This list is neither exhaustive, nor are the descriptions of each tool comprehensive, but the discussion serves to highlight that there are many different ways of conceptualizing social responsibility and many ways to examine each orientation.

For this study, we use a different conceptualization of social responsibility than the previously highlighted studies. We see social responsibility as both a value orientation and as a guiding principle for taking action. Our view of social responsibility focuses on feelings of obligation to help others as both a person and a professional, with a special focus on helping disadvantaged or marginalized populations. Social responsibility is seen as both personal and professional, where individuals can develop the personal and professional orientations independently and potentially to varying degrees. The PSRDM also addresses elements which enable

the bridging and integration of personal and professional views of social responsibility.

2.1 Ethic of care

With the definition of social responsibility used for this study, the Ethic of Care framework provides many useful elements to understand and enhance the PSRDM. Different from other moral theories which are based on fairness and justice, Ethic of Care focuses on the importance of relationships, broadly seen as the co-created connection between the "carer", one who provides care, and the "cared-for" [24]. Essential in Ethic of Care are practices of care and objectivity. Care focuses on the relationship between all parties involved and objectivity encourages an engineer to look outward in the design process, leading to more socially responsible practices.

Moriarty [3] posited that adopting an Ethic of Care in engineering can provide engineers with a basis from which to balance the variety of values that they must address, including efficiency of design, technical needs, and environmental and social sensitivity. She also argued that "the practice of virtues such as care and objectivity by any professional as a professional should help to shape his or her whole character and, in particular, should help to shape for the engineering profession collectively a caring and objective group ethos. In turn, as the ethos of the engineering profession becomes more caring and objective, individual engineers, in drawing from this ethos and living up to it, will become themselves more caring and objective" [3, p. 76]. This aligns with our view of social responsibility as both personal (individual) and professional (collective). Whereas Moriarty speaks about the cyclical influence of one to the other, our framework allows for disconnect between the individual and the collective, between the personal and the professional at the individual level. This has advantages at both the collective and the personal levels. At the collective level, this allows for the situation in which individuals who have high social responsibility remain isolated in the greater profession, working on engineering service activities on their own time with little or no institutional support. At the individual level, it seemed reasonable to consider the potential for a separation between one's views of personal and professional social responsibility. Interviews with engineering students confirmed this perspective where a few students, though very active in volunteer work, spoke directly about how they kept that separate from their views of engineering, intentionally compartmentalizing their lives with service in one bin and engineering in another.

Ethic of Care's focus on relationships also highlights the need for a wider view of stakeholders during the engineering design process, i.e., being aware of all groups that could be affected by the engineering work and, most importantly, engaging those groups in caring relationships throughout the design process. This relates well to the views of Humanitarian Engineering which is a framework focused on "the application of engineering skills or services for humanitarian aid purposes, such as disaster recovery or international development" [25, p. 2]. Ethic of Care also parallels the Design Method and the Problem Solving frameworks which are traditionally used to describe the engineering process. It is stronger than these traditional frameworks towards developing more holistic engineers, however, because it "enables students to become aware of those non-technical dimensions of engineering and navigate through their intricate links" [26, p. 205]. The necessity of recognizing the many non-technical dimensions of engineering projects is central to our view of social responsibility because it focuses on identifying the needs of others and working with all affected parties to find appropriate solutions.

2.2 Underlying theoretical models for the PSRDM

Three theoretical models more directly form the foundation for the PSRDM. Schwartz's [27, 28] altruistic helping behavior model identifies the moral and emotional development that leads to a person taking action to help others. This model formed the basis for the CSAS instrument mentioned above. Ramsey's [29, 30] model for integrating social responsibility into the decision process of scientists is used to describe the development of professional social responsibility. Delve, Mintz and Stewart [31] developed the Service Learning Model based on five-phases of development for people who are already engaged in voluntary community service. This model later formed the basis for the Scale of Service Learning Involvement [32]. Each of these three models is described in more detail below, as well as how they work together to form the PSRDM.

Schwartz's model uses five discrete phases in an accumulative process to describe the development of altruistic behavior. The first phase (*Attention*) contains three sub-phases which categorize (1) the development of an awareness that problems exist, (2) that action needs to be taken, and (3) that one has the ability to address those problems. In order to progress to the next phase, it is critical that the individual believes that they have the skills necessary to help others, allowing for the development of personal norms of motivation. The second phase is the *Motivation* phase which relates to the activation of the one's value system in relation to taking or not taking action. In this phase, Schwartz differentiates

between helping behavior and altruistic behavior by the source of the moral obligation that drives one to take action, either from a social norm or from a personal norm, respectively. This vision of moral obligation plays into the crux of our model whereby individuals feel a moral obligation to act because of their professional skills. The third phase is the *Anticipatory Evaluation* phase where the costs and benefits of engagement are weighed by the individual. The fourth phase is the *Defense* phase where an individual may ''play down'' moral obligation if the costs and benefits are seen as even, therefore upsetting the balance and leading to inaction. This phase only occurs if the costs and benefits from phase three are equal. The final phase is the *Behavior* phase where the decision to act or not act is executed based upon the results of phases one to four.

All five phases are used to support key dimensions in the PSRDM. While Schwartz's model thoroughly develops the stages of progression towards engaging in action, it stops at that point and does not distinguish between peripheral volunteering and deeply connected social engagement. This model also approaches feelings of obligation as general, but the PSRDM includes how one's professional association may also influence his/her development of moral obligation.

Ramsey's model is used in the PSRDM to tie the development of altruistic behavior to the scientific decision making process [29, 30]. This model uses six tenets as prerequisites for creating socially responsible and affective science students. These six prerequisites are: (1) identifying how science plays a role in social issues; (2) the ability to analyze issues, including identification of ''key players'' and how their beliefs and values will influence the solution; (3) the ability to use the scientific problem-solving process to examine the issue more holistically, including social, economic, political, legal and economic ramifications; (4) the ability to evaluate all the evidence gathered to determine the most effective solution; (5) using decision-making models to develop action plans to implement the determined solution; and (6) the ability to execute the plan if it aligns with the individual's value system.

Ramsey's model is not a developmental model as Schwartz's is, and it does not hold a defined linear, sequential relationship between the six tenets. There are, however, parallels between the attributes discussed by Ramsey and the different stages discussed by Schwartz. For example, tenet one, an ability to identify science-related social issues, is similar to the awareness of social issues addressed by Schwartz's first phase, but in Ramsey's model it's specifically related to the involvement of science in social issues. Similarly, tenets three and five relate to one's ability to use scientific skills (problem-solving and decision-making models) and these parallel the ability sub-phase, also in Schwartz's first phase. Using Ramsey's six tenets, in combination with Schwartz's developmental stages, allows us to see how a science-based perspective can be incorporated into the development of social responsibility. In theory, examining the presence of all six of Ramsey's tenets would be important in assessing the development of professional social responsibility in an individual. Neither model, however, address the formative effects of actually engaging in the service of others. Delve et al.'s [31] Service Learning Model is used to explain these effects, specifically the movement from peripheral to full involvement.

The Service Learning Model was developed to focus on community service as an essential aspect of developing strong social values. One of the three development models that the Service Learning Model is based on is Gilligan's Model of the Development of Women's Moral Judgment [10] which also formed a foundation for Ethic of Care. Delve et al.'s model was designed to measure the effects of service-learning educational interventions through five linear, sequential phases, with four key variables for each phase. The four variables are *Intervention* (mode and setting), *Commitment* (frequency and duration), *Behavior* (needs and outcomes), and *Balance* (challenges and supports). Progression through the five phases explains how engagement leads to a deepening commitment and identification with social issues. The first phase is *Exploration* where participants are eager to get involved, but are generally naïve about social issues and are perhaps motivated by external factors such as spending time with friends, or getting a free t-shirt. *Clarification* is the second phase where the individual is trying multiple service experiences, searching for a ''good fit.'' The third phase is *Realization* where the individual begins to grasp larger truths about him- or herself and about service. Generally the individual begins to identify more strongly with a single population or issue in this phase. In the fourth phase, *Activation*, the individual begins to understand more fully the complexity and interrelatedness between their service experiences and larger social issues. The individual may start to become an advocate for the population being served at this phase. In the last phase, *Internalization*, the individual has fully integrated her/his service experiences into her/his daily lives. At this point, the individual is willing to adjust her/his life and career to better align with the personal views that were developed through deep engagement in service.

The five phases of Delve et al.'s model describe how involvement in service deepens one's connection with social issues, eventually providing a moral

grounding that affects that person's life choices, such as a choice of career. In the PSRDM, this model is used to describe how engagement in engineering service can deepen one's sense of professional social responsibility by grounding their views of obligation in the social values developed through their action.

The PSRDM draws from all three of these models to explain the development of both personal and professional social responsibility through stages of: recognition that problems exist, an awareness of an ability to act, feelings of moral obligation to act, evaluation of costs and benefits, taking action, and into the five stages of deepening personal and professional social responsibility. Schwartz's model provides a basis to talk about how an individual develops feelings of obligation to help others, leading to some form of action or inaction based upon those beliefs. Ramsey's model provides a roadmap for how to include social issues into the engineering design process. Relating to Schwartz's model, using Ramsey's model helps allow the integration of the development of moral obligation with the engineering design process through a recognition of the impacts of engineering on society, and a belief that a broader range of social perspectives are necessary for successful engineering projects. Finally, the Service Learning Model from Delve et al. provides a way to discuss the moral grounding that occurs through engagement in service, and how engineering service can further develop social responsibility. Schwartz's model lacks a discussion of the effects of engaging in service, and Ramsey's model lacks the continued personal growth that occurs once an individual adopts a wider, more holistic perspective of design. The Service Learning Model addresses how engaging in service further develops both the individual and professional sense of obligation to help others in a cyclical fashion. By combining the three models we can discuss the development of personal and professional social responsibility within the context of the engineering profession, including how engagement in engineering service can deepen one's sense of moral obligation to help others.

3. The professional social responsibility development model

The PSRDM uses three realms to address the development of social responsibility: Personal Social Awareness, Professional Development, and Professional Connectedness. The Personal Social Awareness realm describes the development of feelings of moral obligation to help others separate from one's professional identify and draws from the *Attention* and *Motivation* Phases in Schwartz's model. The Professional Development realm describes the development of professional abilities, with a focus on how those abilities could be used to help others. This realm draws from all six of Ramsey's tenets and from the *Attention* Phase of Schwartz's model. The Professional Connectedness realm describes how a moral obligation to help is tied to one's professional identity and how engagement in service influences that feeling of obligation. This realm combines Schwartz's *Motivation* and *Costs and Benefits* Phases with Ramsey's model and draws from Delve et al.'s model to characterize the personal development that occurs through engaging in service. Three dimensions comprise both the Personal Social Awareness and the Professional Development realms. The Professional Connectedness realm results from the combination of the first two realms and is a cyclical pathway whereby taking action leads to more developed personal and professional social responsibility. The development and relationships between these three realms was influenced by qualitative and quantitative data, discussed in the following sections. The PSRDM is shown in Fig. 1.

Though this model describes the development of social responsibility, it is important to note that the progression within each realm, through each dimension, is not a strictly linear or stage-like process. For the purposes of this paper, and the framework at large, dimensions are discussed separately, but are also hypothesized to be related to one another. Evidence for the relationships between dimensions is presented. Future work will gather evidence to examine the developmental relationships between different dimensions and levels within each dimension, but at present, such evidence is not available.

In addition to providing descriptions of each dimension, quotes from a series of in-depth interviews with engineering students are given related to the influences on each of the three realms. Twenty-five semi-structured interviews were conducted primarily with senior (n = 12) and graduate (n = 12) engineering students in Mechanical (n = 7), Civil (n = 13), and Environmental (n = 4) programs. One Civil Engineering student was a junior and one graduate student was in Aerospace Engineering.

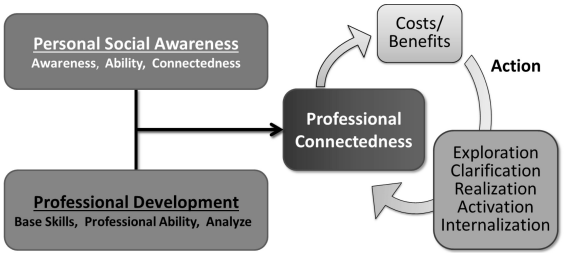

Fig. 1. Professional Social Responsibility Development Model.

Fifteen of the interviewees were males and ten were females. Students were solicited through contacts with professors in each department who were asked to provide names of students who they felt represented a range of beliefs and experiences with respect to social responsibility (see [33] for more details about the interviewees' demographics, selection process, and interview formats). Interviews lasted about one hour and no incentives were provided.

The original purpose of the interviews was to understand what students believed their personal and professional social responsibilities were and what life experiences had informed those beliefs. Interview questions focused on why students chose engineering as a major, their career aspirations, how they defined social responsibility, their views of the role of an engineer in society, and what life experiences formed the foundations of their views of personal and professional social responsibility. Prior to each interview, students were asked to take a written survey related to personal and professional social responsibility in engineering. Questions from this survey became topics of discussion in some of the interviews. Deductive coding was used to analyze the interview data, drawing from definitions of each dimension which were developed with a panel of experts in engineering and engineering education. Two reviewers coded each interview for evidence supporting students' views and development of each of the eight dimensions. Samples from three of these coded interviews are used as evidence for how students speak about these different realms, and about life experiences that influenced those students' views. Pseudonyms are used for each student, consistent with Institutional Review Board (IRB) protocols.

3.1 Personal social awareness realm

The Personal Social Awareness realm describes the development of altruistic behavior, paralleling Schwartz's model for altruistic behavior development. The first dimension is *Awareness* and addresses an awareness that others are in need. *Awareness* includes both knowledge of people or groups who are in need, and also of the relationships and interconnections between complex social issues and those in need. The development of *Awareness* could come from external sources such as friends, media, the news, school, or from personal experiences, such as volunteering at a soup kitchen or helping a family member with a disability.

The second dimension is *Ability* where one recognizes that he/she has the ability to do something to help others who are in need. Factors which could influence the development of *Ability* include: observing others who take action and believing that one could as well, support from family, friends, or mentors that one could be affective, or reflecting upon past experiences and believing that the individual did have an effect. All of these influences could build an individual's belief or confidence that he/she could have a positive effect in the future.

The third dimension of the Personal Social Awareness realm is *Connectedness*, a term that comes from the CSAS model, and addresses a feeling of moral obligation to help others. The development of *Connectedness* is rooted in Schwartz's use of personal or social norms as motivators. For this dimension motivations could come from a wide variety of sources, either external or internal, such as religion, just for fun, social guilt, or a sense of spiritual, civic, or moral obligation. In the Personal Social Awareness realm there is no relation to one's professional skills, and this realm could describe the development of social responsibility in any person.

Qualitative Evidence Related to Influences on the Personal Social Awareness Realm: Owen was a graduate student in Aerospace Engineering. He completed his undergraduate education at a liberal arts school, finishing with an English degree. After graduating, he went and worked at a public mental health facility and spoke of that experience in relation to influences on his views of social responsibility. He said:

> ". . . there was a guy who was the same age as me, who was really intelligent and he'd read all of the science magazines I brought. He was deeply, deeply mentally ill, like very strong schizophrenia and the medications required to keep him under control would make him sleep twenty hours a day. And I remember just watching this guy, you know, he was only a couple years younger than me. . . and so it really struck home to me that just for a very small chance that I had no control of, I could be in his position."

Owen spoke about many personal experiences like this one which helped him to recognize that there are others who need help, developing both his awareness of needs and in seeing ways in which he could help others. When Owen was asked to describe what social responsibility meant to him, he responded:

> "Simply put, it's the responsibility we have for the privileges that we've received. I think a lot of progressives talk about this, though I don't really put myself in the camp, but they point out that most of us, you and me for example, are here because we have all sorts of advantages that have been given to us. Least of which is being born in the United States where we have schools and roads and all sorts of stuff. And we have a responsibility to make use of those advantages in a way that helps everyone else. . . to recognize that we don't deserve the benefits that we have necessarily. It's that we should act according to that. That's how I define social responsibility."

Here we see how Owen is describing the source of his feelings of moral obligation. He believed that he had social benefits which were gained through no effort of his own, and that this brought with it a responsibility to use those advantages to help others. Later in the interview, he spoke about how this feeling of obligation, combined with his experiences at the mental health facility and other personal life events, led him to strive for an "empathetic realization" that there are social problems which need to be addressed. In Owen, we see how his Personal Social Awareness has developed because of personal interactions with others who are disadvantaged and how his beliefs have developed to include the recognition of personal advantages, leading to a belief in the responsibility for him personally to "act accordingly" to help others.

3.2 Professional development realm

The Professional Development realm addresses the development of professional skills in relation to the need to solve social problems. Our view of professional development with respect to social responsibility aligns closely with Vanasupa et al.'s definition as "the responsibility of engineers to carefully evaluate the full range of broader impacts of their designs on the health, safety and welfare of the public and the environment" [34, p. 374]. The Professional Development realm consists of the three dimensions described below.

The prerequisite for engaging in action as a professional is the development of *Base Skills*, which is the first dimension in this realm and encompasses the trade-specific skills necessary to be, for example, an effective engineer. An acknowledgment of the need to achieve a balance of both technical and professional skills is critical in the development of base skills with respect to social responsibility. In the simplest case, these skills would be developed through traditional educational systems, internships, or through the practice of engineering. Mentors who would teach and exemplify a larger understanding of the engineering profession would be critical agents for the development of base skills in this way.

The second dimension is *Professional Ability* which addresses the recognition that one's professional skills give them the ability to help others. In engineering, this includes recognition that engineering solutions have the ability to help solve social or environmental problems that face society. Similar to *Base Skills*, *Professional Ability* could develop through exposure by mentors or through personal experiences to understand the ways in which engineering could positively affect society and contribute to solutions for complex social issues.

The third dimension is *Analyze* which addresses the ability to examine social issues from a professional perspective. This dimension is characterized by views of who the stakeholders are for engineering projects and how they should be involved in the decision making process. The elements which would aid in the development of this dimension are similar to the other dimensions in this realm.

Combined, this path describes the progression of a professional from the development of skills to a recognition that those skills give her/him a unique ability to help others. As shown in Fig. 1, the Personal Social Awareness and Professional Development realms run in parallel, each possibly developing independently. The bridging between these two is Professional Connectedness, described in the third realm.

Qualitative Evidence Related to Influences on the Professional Development Realm: Beau was a senior Civil Engineering student who had two consecutive internships working on civil projects in rural Alaska. In one of those summers, he was involved with "the business side of engineering . . . go[ing] out to villages and taking surveys, asking people how their plumbing and sewage systems were. . ." This experience exposed Beau to a wider view of engineering, to include more business applications such as grant writing and surveying those affected by his work, aiding in the development of his *Base Skills*.

These internships also influenced his development of *Professional Ability*. He said, ". . . those bush Alaska villages are like 50 years behind the rest of the country, so it's really interesting to see how those [water and wastewater treatment plants] affected life in those villages." This exposure showed him directly how engineering projects could have a tremendous effect on solving social issues, specifically improving the quality of life in rural Alaskan villages.

Beau talked about a different experience that seemed to influence his views of *Analyze*. He described a class experience where they visited a large construction site in a neighborhood setting, saying,

> ". . . we met with the project manager for these buildings . . . and that was pretty interesting because the project manager is in charge of a lot of non-engineering related things. There's a lot of houses neighboring the construction site and they're dealing with those people, whether they wanted the noise down, or construction at certain times . . . so that was another good example of seeing how engineering projects can relate to the community."

Beau spoke about valuing the "non-engineering" skills and gave good examples of how the community needed to be involved in many engineering decisions in order for the project to be successful. Through his exposure to the construction site, and

the project manager as a sort of mentor, he began to see the importance of a larger view of stakeholders for construction projects.

3.3 Professional connectedness realm

The Professional Connectedness realm is characterized by a cyclical process centered on a sense of moral obligation to help others because of the professional skills that one possesses (*Professional Connectedness*). The combination of the Personal Social Awareness and the Professional Development realms support the development of moral obligation in relation to professional abilities. Some elements of *Professional Connectedness* would include public safety, environmental protection, pro bono work, and viewing engineering projects as service. A person's engineering identity would also be affected by their views of professional moral obligation, influencing the type of engineer they intended to be in society.

Similar to the Service Learning Model, the PSRDM holds that increased *Professional Connectedness* occurs through action, specifically service engagements as engineers. The cyclical nature of this realm is based in the consideration of C*osts and Benefits* of engaging in action, and then progressing through the deepening levels of relationship with social issues. This cycles the participant back, but with a potentially higher sense of moral obligation into the *Professional Connectedness* dimension. As an individual engages in more action, he/she would move further in the stages of the Service Learning Model and therefore deeper in *Professional Connectedness*, meaning that he/she would develop stronger beliefs of personal and professional social responsibility. The *Costs and Benefits* dimension addresses both how an individual views service work, but also the degree to which he/she recognizes the various costs and benefits and how that affects his/her decision to act or not.

Qualitative Evidence Related to Influences on the Professional Connectedness Realm: Laura was a graduate student in Environmental Engineering. She strongly tied her desire to serve communities with her abilities as an environmental engineer. She said, "I see my responsibility [as an engineer] as making their community better or safer through remediation, providing them with an environment that is less polluted." When she was asked about factors which influenced this desire, she pointed to many volunteer opportunities she had taken in high school and college. She also talked about a course in water and sanitation which "really opened [her] eyes" to many of the environmental issues which affect developing communities.

Speaking both to her *Professional Connectedness* and recognition of the *Costs and Benefits*, she said,

> "I just feel like engineering is different, I view it as like my job is doing something that is socially good. So I feel like it's different than my boyfriend [who is] a finance major, and there's part of me that just doesn't understand, like, it's basically just to make money. . . I don't know, it's just like the social responsibility is really different. A lot of engineers, especially Environmentals, I think, just really wanted to do good and to make a difference. And that's why we got into it. Like we're good at math and science, and we don't care about the pay as much. We want to do good things. I think a lot of us could've been [Chemical Engineers] and worked for oil companies if we wanted, but there's a reason we didn't. And I think that's a part of what I feel like social responsibility is, using my job to make a difference."

For Laura her identity as an engineer was directly tied to her ability and responsibility to help others by repairing and protecting the environment, giving evidence to her views of *Professional Connectedness*. Also, through her development of *Professional Connectedness*, she was willing to accept some sacrifices (pay) in order to connect her identity of service to her identity as an environmental engineer.

The PSRDM has been developed and revised through several interactions. The initial conception of the Professional Connectedness Realm was a linear, sequential progression through the stages of the Service Learning Model. After conducting interviews and looking at initial survey items to address each dimension, we found that the boundaries between each stage were blurred and it was difficult to develop survey items to uniquely address each sub-stage. Also, each stage ultimately related back to the idea of one's feelings of obligation to help others as a professional. Therefore we changed the professional connectedness realm to the current cyclical understanding to support the idea that action ultimately increases overall feelings of professional connectedness, and that all the stages of the Service Learning Model could reside in that dimension.

4. Operationalizing the PSRDM

There are many ways in which the PSRDM could be operationalized for both qualitative and quantitative studies of the development of social responsibility in professionals including survey items, interview protocols, or *a priori* codes for analyzing ethnographic data. The Engineering Professional Responsibility Assessment (EPRA) is one way in which the PSRDM has been operationalized. A brief overview of this tool and some survey results from a multi-institutional distribution are provided to exemplify the practical implementation of the PSRDM.

EPRA was developed to measure student beliefs related to the eight dimensions of the PSRDM through 50 7-point Likert-items where students

Table 1. Sample items for EPRA tool for each PSRDM dimension

Dimension	Abbreviation	# of Items	Sample Item
Awareness	Aware	5	"There are people who have needs which are not being met"
Ability	Ability	4	"I can have an impact on solving problems that face my local community"
Connectedness	Conn	4	"It is my responsibility to take some real measures to help others in need"
Base Skills	Base	5	"How important are ethics for a professional engineer?"
Professional Ability	ProfAb	4	"Engineers can have a positive impact on society"
Analyze	Analyze	5	"It is important for engineers to consider the broader potential impacts of technical solutions to problems"
Professional Connectedness	ProfCon	19	"I feel called by the needs of society to pursue a career in engineering"
Costs/Benefits	CB	4	"I would be willing to have a career that earns less money if I were serving society"

are asked to mark their agreement from "Strongly Disagree" to "Strongly Agree" to a set of questions, or items. EPRA was developed through multiple iterations, and has strong evidence of reliability and validity [38]. Table 1 provides the number of items in the survey tool to measure each dimension of the PSRDM and gives an example of each. Examining how engineering students respond to questions in each dimension can give insight into students' attitudes and beliefs of personal and professional social responsibility.

The data provided here comes from a field test at five diverse institutions, targeting first-year, senior, and graduate students in Civil, Environmental, and Mechanical Engineering programs. The survey was sent electronically at the beginning and end of the 2012–2013 academic year and students were provided with monetary compensation ($5 and $10, respectively) for the completion of each survey. In total, 1000 students completed the survey at the beginning of the year and 698 completed it at the end. Only students who completed the survey at the first administration were invited to complete the second. Results from the first administration are used for the example provided in this paper. For a more complete description of the institutions, survey methods, and response population from these administrations, see [39].

Figure 2 shows the average scores for each dimension from the beginning of the year field test, as well as one standard deviation above and below the average to exemplify the spread of responses. What this shows is that, across the entire sample population, students agreed more strongly with questions relating to their awareness that there are people in need (*Aware*), but agree less with questions about their personal or professional obligations to help others (*Conn* and *ProfCon*, respectively). The students surveyed also agreed very strongly, and with a smaller standard deviation, to questions about the importance of base skills in engineering and the ability for engineering to have a positive effect on society (*ProfAb*).

Results such as these can be used to compare student views of social responsibility between different demographic groups such as gender, aca-

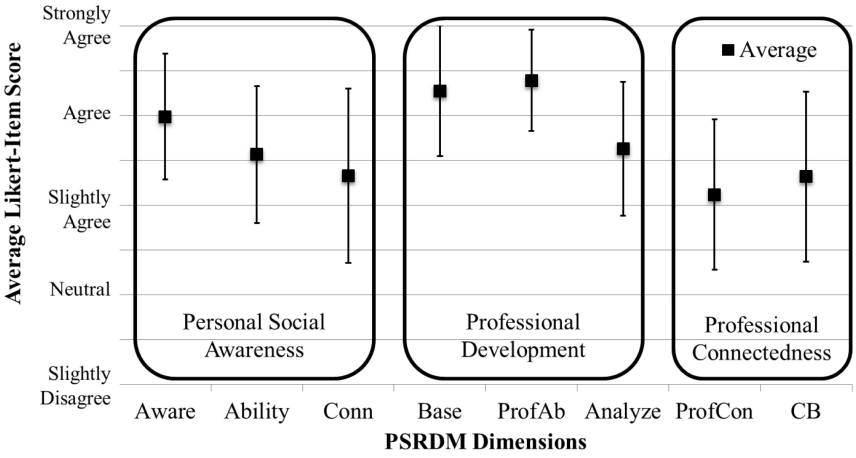

Fig. 2. EPRA Dimension Average Scores and +/- One Standard Deviation.

demic rank, major, or institutions. They can also be used to assess the effectiveness of educational interventions designed to affect the development of social responsibility such as Service-Learning pedagogies or ethics courses. The data presented here represents just one way in which the PSRDM could be operationalized and is provided as an example of the practical implementation of this framework. This framework could be used in many other ways, to guide a wide variety of study types, at better understanding the development of social responsibility in professionals.

5. Future work

The framework presented in this paper is intended as a blueprint for future work that would examine the development of social responsibility to include professional skills and abilities, and to develop methods to identify an individual's levels of social responsibility. Efforts are currently underway to develop a survey instrument to identify degrees of agreement with each dimension, as well as factors which may influence the development of social responsibility in engineering students. This framework is also being used to examine the effects that engaging in engineering service as students has on their long term career pathways as engineering professionals. It could also be used for longitudinal studies, to examine the ways in which students or professionals develop in each realm, relating that development to educational, professional, or other life experiences. In this way, educational interventions aimed at increasing social responsibility could be designed.

6. Conclusions

There is a need in the engineering profession for more holistic engineers who use and value a diverse range of skills, both technical and professional. Views of personal and professional social responsibility could provide a solid foundation from which those skills and perspectives develop. The framework presented here, the PSRDM, provides a blueprint from which to understand the development of personal and professional social responsibility in engineers. Rooted in the Ethic of Care, this framework helps to advance the understanding of the role of the engineer in society and how the virtues of care and objectivity can better enable engineers to work on complex social problems in responsible and sustainable ways. As a foundation for future studies and the development of assessment tools, such as EPRA, the PSRDM will aid engineering educators to create and assess educational interventions to help develop more socially responsible engineers, emphasizing the importance of many professional skills such as ethical development and the understanding of the impacts of engineering decisions on society.

Acknowledgements—This material is based upon work supported by the National Science Foundation under Grant No. 1158863. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. Additional funding was provided through an institutional fellowship for Excellence in STEM Education.

References

1. W. Easterly, *The white man's burden: Why the west's efforts to aid the rest have done so much ill and so little good*, New York: The Penguin Press, 2006.
2. ABET, *Criteria for Accrediting Engineering Programs Effective for Evaluation During the 2009–2010 Accredidation Cycle*, ABET Engineering Accreditation Commission, 2008.
3. G. Moriarty, Ethics, Ethos and the Professions: Some Lessons from Engineering, *Professional Ethics*, **4**(1), 1995, pp. 75–93.
4. Harvard Kennedy School of Government, *Corporate Social Responsibiltiy Initiative*, Harvard University, 2008. [Online]. Available: http://www.hks.harvard.edu/m-rcbg/CSRI/init_define.html. [Accessed 24 May 2013].
5. NAE, Educating the Engineer of 2020: *Adapting Engineering Education to the New Century*, Washington DC: The National Academies Press, 2005.
6. ASCE, *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, 2nd Edition*, ASCE, 2008.
7. AAEE, *Environmental Engineering Body of Knowledge*, American Academy of Environmental Engineers, 2009.
8. Engineers for Social Responsibility, *Engineers for Social Reponsibility—Our Objectives*," n.d.nz. [Online]. Available: www.esr.org.nz. [Accessed 14 May 2013].
9. The Calling of an Engineer, *The Calling of an Engineer – Background*, 2013. [Online]. Available: www.ironring.ca/background.php. [Accessed 14 May 2013].
10. C. Gilligan, *In a Different Voice: Psychological Theory and Women's Development*, Campbridge, MA: Harvard University Press, 1982.
11. I. Nair, Ethics of Care, in *Encyclopedia of Science, Technology, and Ethics*, Detroit, MI, Macmillan Reference USA, 2005, pp. 695–700.
12. V. Held, *The Ethics of Care: Personal, Political, and Global*, New York, NY: Oxford University Press, 2006.
13. A. R. Carberry, *Characterizing Learning-Through-Service Students in Engineering by Gender and Academic Year*, Tufts University, 2010.
14. J. Wang, E. Patten, R. Shelby, F. Ansari and L. A. Pruitt, Leadership and Service Learning Improves Confidence of Engineering Skills in Women, in *Proceedings of the 2012 ASEE Annual Conference & Exposition*, San Antonio, TX, 2012.
15. J. J. Duffy, L. Barrington and M. A. Heredia Munoz, Attitudes of Engineering Students from Underrepresented Groups Toward Service-Learning, in *Proceedings of the Annual ASEE Conference and Exposition*, Vancouver, BC, 2011.
16. J. Smith and A. McKitrick, Facilitating Transformation through Education: Promoting Teaching of Social Responsibility and Civic Education for Democracy, in *Research for What? Making Engaged Scholarship Matter*, Information Age Publishing, Inc., 2010, pp. 47–69.
17. A. Finley, *Civic Learning and Democratic Engagements: A Review of the Literature on Civic Engagement in Post-Secondary Education*, Association of American Colleges & Universities, 2011.
18. N. O'Neill, *Promising Practices for Personal and Social*

Responsibility: Findings from a National Research Collaborative, Association of American Colleges and Universities, 2012.
19. S. A. Lathem, M. D. Neumann and N. Hayden, The Socially Responsible Engineer: Assessing Student Attitudes of Roles and Responsibilities, *Journal of Engineering Education,* **100**(3), 2011, pp. 444–474.
20. L. Carter, Making ethical engineers: Engineers for Social Responsibility, in *Proceedings of the 2011 AAEE Conference*, Fremantle, Western Australia, 2011.
21. Association of American Colleges and Universities, *Character Traits Associated with the Five Dimensions of Personal and Social Responsibility*, Association of American Colleges and Universities, Washington, D.C., n.d..
22. A. H. Shiarella, A. M. McCarthy and M. L. Tucker, Development and Construct Validity of Scores on the Community Service Attitudes Scale, *Educational and Psychological Measurement,* **60**(2), 2000, pp. 286–300.
23. E. H. Bauer, B. Moskal, J. Gosink, J. Lucena and D. Munoz, Faculty and Student Attitudes Toward Community Service: A Comparative Analysis, *Journal of Engineering Education,* **96**(2), 2007, pp. 129–140.
24. N. Noddings, Caring: *A feminine apporach to ethics & moral education*, Berkeley, CA: Univ. of California Press, 2003.
25. R. C. Campbell and D. Wilson, The Unique Value of Humanitarian Engineering, in *Proceedings of the Annual ASEE Conference and Exposition*, Vancouver, BC, 2011.
26. M. Pantazidou and I. Nair, Ethics of Care: Guiding Principles for Engineering Teaching & Practice, *Journal of Engineering Education*, **88**, 1999, pp. 205–212.
27. S. Schwartz, Normative influences on altruism, *Advances in experimental social psychology*, **10**, 1977, pp. 221–279.
28. S. H. Schwartz and J. A. Howard, Helping and Cooperation: A Self-Based Motivational Model, in *Cooperation and Helping Behavior: Theories and Research*, New York, Academic Press, Inc., 1982, pp. 327–353.
29. J. Ramsey, The Science Education Reform Movement: Implications for Social Responsibility, *Science Education*, **77**(5), 1993, pp. 235–258.
30. J. Ramsey, A Curricular Framework for Community-Based STS Issue Instruction, *Education and Urban Society*, **22**(1), 1989, pp. 40–53.
31. C. L. Delve, S. D. Mintz and G. M. Stewart, Promoting values development through community service: A design, *New Directions for Student Service,* 1990, pp. 7–29.
32. C. Olney and S. Grande, Validation of a Scale to Measure Development of Social Responsibiltiy, *Michigan Journal of Community Service Learning*, 1995, pp. 43–53.
33. N. Canney, T. Bowling and A. Bielefeldt, In their own words: Engineering students' views on the relationship between the engineering profession and society, in *Proceedings of the ASEE Annual Conference & Exposition*, Atlanta, GA, 2013.
34. L. Vanasupa, L. Slivovsky and K. C. Chen, Global challenges as inspiration: A classroom strategy to foster social responsibility, *Science and Engineering Ethics,* **12**(1), 2006, pp. 373–380.
35. J. Schneider, J. A. Leydens and J. Lucena, Where is 'Community'?: Engeinering education and sustainable community development, *European Journal of Engineering Education,* **33**(3), 2008, pp. 307–319.
36. B. Amadei and R. Sandekian, Model of Integrating Humanitarian Development into Engineering Education, *Journal of Professional Issues in Engineering Education and Practice,* April 2010.
37. K. M. Passino, Educating the Humanitarian Engineer, *Science and Engineering Ethics,* **15**, 2009, pp. 577–600.
38. N. Canney and A. Bielefeldt, Validity and Reliability Evidence for the Engineering Professional Responsibility Assessment Tool to Measure Social Responsibility in Students, *Journal of Engineering Education*, under review.
39. N. Canney, *Assessing Engineering Students' Understanding of Personal and Professional Social Responsibility*. Ph.D. Dissertation, University of Colorado, 2013.

Nathan Canney, Ph.D., P.E., is an instructor in Civil and Environmental Engineering at Seattle University. His doctoral work was done at the University of Colorado, Boulder in the Department of Civil, Environmental, and Architectural Engineering with a focus on engineering education. Nathan has bachelor's degrees in Civil Engineering and Mathematics from Seattle University and a master's degree in Civil Engineering from Stanford University, with a focus on structural engineering. His current research focuses on the development of personal and professional social responsibility in engineering students.

Angela Bielefeldt, Ph.D., P.E., is a Professor at the University of Colorado Boulder in the Department of Civil, Environmental, & Architectural Engineering (CEAE). She is currently the Associate Chair for Undergraduate Education in CEAE and has served as the ABET assessment coordinator since 2008. She began incorporating service-learning (SL) projects into the capstone design course for environmental engineering in 2001. This began her journey to determine how to rigorously assess the learning outcomes for students who worked on SL projects as compared to other types of projects in the course. Her engineering education research interests also include students' attitudes and knowledge about sustainable engineering, engineering ethics, and attracting and retaining women in engineering.