In their own words: Engineering students' views on the relationship between the engineering profession and society

Nathan E Canney P.E., University of Colorado Boulder

Nathan Canney is a doctoral candidate in Civil Engineering, with a research focus on engineering education. Nathan has bachelor's degrees in Civil Engineering and Mathematics from Seattle University and a master's degree in Structural Engineering from Stanford University. His current research focuses on the development of personal and professional social responsibility in engineering students.

Tess Bowling, University of Colorado at Boulder
Dr. Angela R Bielefeldt, University of Colorado, Boulder

Dr. Angela Bielefeldt, P.E., is a professor at the University of Colorado Boulder in the Department of Civil, Environmental, and 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.

In their own words: Engineering students' views on the relationship between the engineering profession and society

Abstract

As the engineering profession advances, there is a recognition that engineers must interact across disciplinary and cultural boundaries to successfully address complex problems. Directly or indirectly, an engineer's work affects society and therefore it is critical that they give full consideration to the relationship between the engineering profession and society throughout the design process. Many professional engineering organizations are calling for engineers with a better understanding of the societal context in which they work [1, 2, 3, 4], but there is no clear pathway to teach this understanding to students, nor how students will interpret what they are provided. With the profession and engineering educators pushing towards this goal, it seems critical to talk with students to find out how they view the engineering profession in society and, more specifically, how they see themselves benefitting society as engineers.

Twenty-five students representing Civil, Environmental, Mechanical, and Aerospace Engineering, primarily Senior and Graduate students, engaged in conversations around their views of social responsibility and the role of engineering in society. These interviews lasted 30 to 60 minutes and were recorded, transcribed, and analyzed using issue-focused emergent coding[5]. Three different interview methods were used to elicit conversation; semi-structured interviews, interviews focused on questions from a survey about attitudes of personal and professional responsibility, and finally a variation of Rappaport Timelines[6] used to examine life events which students identified as formative for their views of engineering and society. This paper explores several themes that emerged from these conversations including: (a) if a desire to help society attracted students to engineering; (b) how students talk about engineers interacting with society; and (c) what role feedback from society, the community, or the client should play in the engineering design process.

Purpose

> "While engineering is a profession with a strong ethical dimension, and while we have explicitly stated in our various codes of conduct that we must hold paramount the public safety, there has been until very recently no reference to addressing two of the most important issues of our times – poverty and underdevelopment and environmental degradation. It is as if engineering as a profession is somehow excused from such deliberations or that if we serve our employers faithfully and professionally, it will somehow all work out in the end. I do not believe it will somehow work out in the end but rather believe that we, as engineers, need to change the way we envisage our profession" [7] (p. 1).

If we are to elevate the vision of engineering in society, as Catalano proposes, the conversation must begin with engineering students as they form their vision of the engineering profession and its relationship with society. In changing the view of the engineering profession, some engineering educators have called for a greater focus on service[8], pro bono work [9], or community centered design[10]. Others have focused on how different teaching methods, such as Project-Based Service-Learning, may be effective tools for teaching students to have a larger view of the role of engineering in society[11, 12, 13]. One study surveyed students regarding their beliefs about

service as a part of the engineering profession in general, and found that the majority of students agreed that more service should be incorporated into the engineering profession [14, 15].

The purpose of this study is to examine how engineering students describe the relationship between the engineering profession and society by asking students to be introspective about their experiences. The role of engineering in society is approached through the lenses of professionalism, ethics, responsibility, and service. Additionally, issues of service as a motivating factor for students to choose engineering and how perspectives differ along disciplinary lines are examined. The ways in which students talk about these topics, including the examples they use to highlight their views, shows directly and indirectly what students believe the role of the engineer in society is and is reflective of the view of the profession that they have formed through their college experiences. This paper examines different perspectives of engineering students.

Methods

The data for this study were obtained in 25 interviews conducted with engineering students at a large public university. The interviews lasted 30-60 minutes and were non-incentivized. Students' names were solicited from professors in Civil, Environmental, Mechanical, and Aerospace Engineering, who provided the names of students whom they felt represented a wide range of beliefs with respect to professional responsibility. Because student names were gathered from instructors, the majority of students were Senior and Graduate students; this was appropriate given that the topics of discussion involved their experiences in engineering and views of the engineering profession. Students were invited via email to be interviewed about their opinions and experiences related to professional responsibility. At the beginning of each interview, students were consented in accordance with IRB procedures. Next, the students completed the Engineering Professional Responsibility Assessment (EPRA) tool[16] - a written, survey utilizing Likert-style questions focused on views of personal and professional social responsibility in engineering. Eight of the students had taken the EPRA tool in one of their classes within a month of doing the interview, and so these students did not retake it. The survey required approximately 15 minutes to complete, and then the interview continued. All interviews were conducted by the same individual, a male student conducting PhD research in engineering education. All interviews were recorded and transcribed.

Table 1. Student Participant Information

Interview method	# students	Gender	Engineering Majors Civ/Env/Mech/Aero	Year Jr / Sr / Grad
Semi-structured	11	M – 6	5/0/0/1	0/2/4
		F – 5	2/3/0/0	0/2/3
Survey focus	8	M – 5	3/0/2/0	1/2/2
		F – 3	1/1/1/0	0/2/1
Timelines	6	M - 4	1/0/3/0	0/3/1
		F – 2	1/0/1/0	0/1/1
Total	**25**	**M 15**	**9/0/5/1**	**1/7/7**
		F 10	**4/4/2/0**	**0/5/5**

The distribution of interview methods and demographic breakdown of the sample population are in Table 1. Three different interview methods were used to encourage conversation with the

students. The first method was semi-structured interviews, with questions about why the students chose engineering as a major, what they hoped their career would look like, how they defined social responsibility, what experiences in their life had influenced that view, if any classes or projects had been particularly formative with respect to their view of social responsibility, what it meant to them that engineering is considered a profession, and their beliefs about pro bono work in engineering. These seven questions were asked of all students who were interviewed using this method.

The next interview method used was survey-focused, where students were asked to explain the thought processes behind their responses to the EPRA questions. Students generally set the pace, deciding which questions to address and which to skip. Occasionally the interviewer would ask the students about their opinions on particular questions, or about why they selected a particular response. The interviewer worked to elicit examples or to hear the thought process of the student while answering a given question. Discussions about questions generally led to further conversation about life events that were influential in their perspectives or general attitudes toward service in engineering.

The final interview method used a variation on Rappaport timeline exercises[6]. In this method students were given a sheet of paper with three lines on it. An example of a time line is given in Figure 1. Three lines were labeled on the left with "Before College", "Since Starting College", and "In the Future", respectively. Students were then verbally instructed to mark at least three events on the first line that "were influential to your studying engineering", to mark at least three events on the middle line "since coming to college that have influenced your view of engineering", and to mark at least three things on the bottom line that they "hope to do in the future as an engineer." After students had marked the timelines, they were asked to discuss what they wrote and why. This method was chosen for two reasons: 1) to provide a tangible element to guide the conversation which seemed to make students more comfortable in talking about their views, and 2) to encourage introspective action by the students about events in their lives that were formative, and thereby to think about what their beliefs and opinions were. If there was time remaining after discussing the timelines, the interviews would then shift to talking about the EPRA tool and their general opinions about the topics of that survey.

Although the analysis in this paper does not attempt to make generalizations based upon the interview methods or demographics, this information is provided in Table 1 to give a better understanding of the context in which the data were acquired. In particular, the students who were interviewed may not be representative of the engineering student population as a whole. Because their names were obtained from professors, they were most likely individuals who stood out either as exemplary students or as students who were active in extracurricular activities such as ASCE, EWB, or as research assistants. Also because this was voluntary, students who were willing to participate in the interview may have had preexisting interest in the interview topic, professional responsibility, and that was why they agreed to participate.

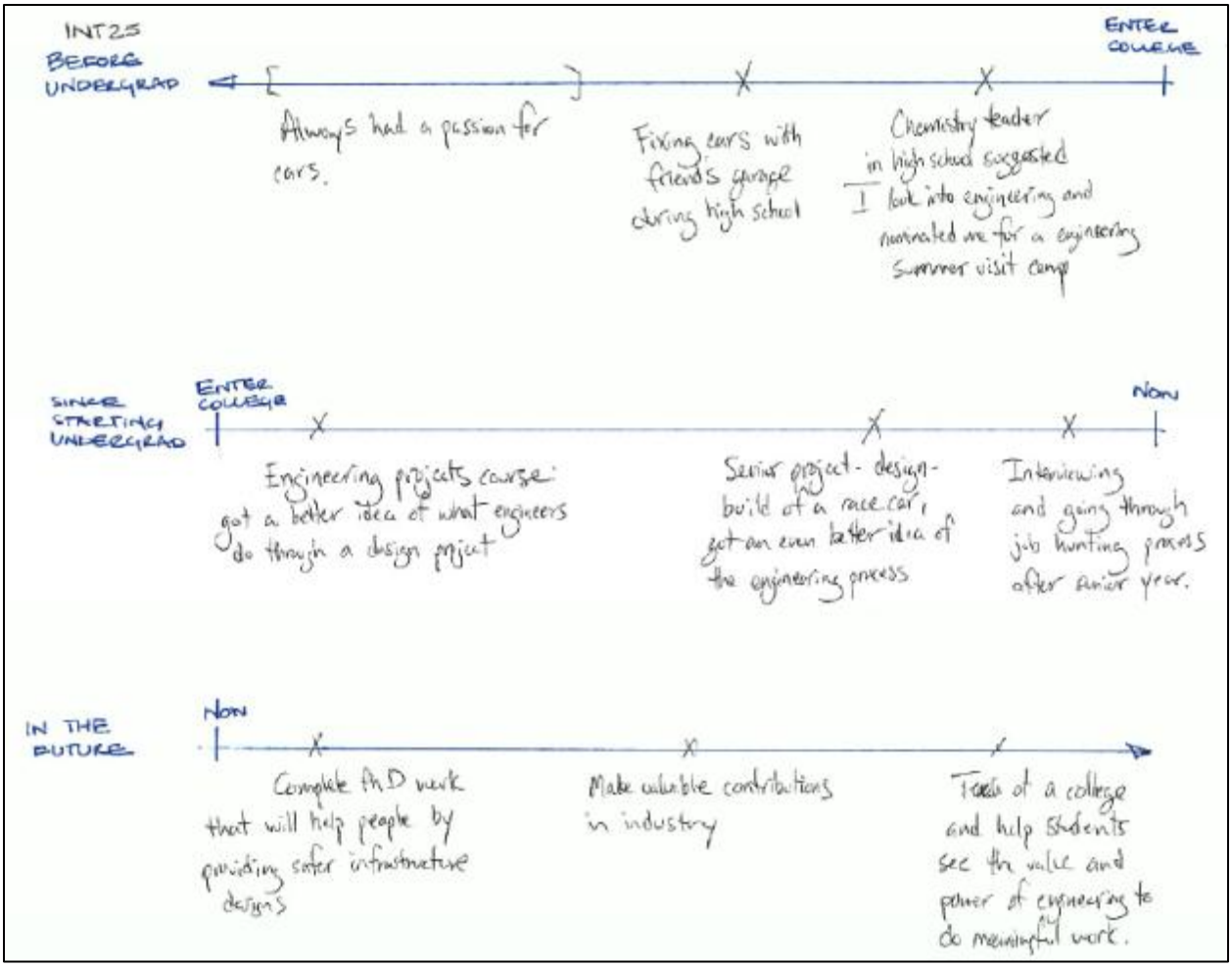

Figure 1. Sample Student Timeline Exercise

In analyzing the student interviews, an issue-focused approach was used where themes were determined in an emergent fashion from the data[5]. Three reviewers independently created code books off of combinations of four different interviews. The reviewers were the three co-authors of this paper: the PhD student who conducted the interviews, an undergraduate research assistant, and an engineering professor. These code books were discussed and consolidated, then used again by the three reviewers on four new interviews. New codes were added and this became the final code book which was used to code all interviews. Eleven major themes were found, with four to twenty sub-themes for each. In the reporting of the data, student names have been changed to protect the participant's identities, consistent with IRB guidelines.

Results/Discussion

The open-ended, narrative nature of these interviews produced a wide range of topics that could be discussed and analyzed, including what attracted students to engineering, how classes or internships shaped their views, and students' expectations for their future careers in engineering. This paper focuses on how the students talked about the relationship between the engineering profession and society. Three themes emerged from the interviews: (a) how perceptions of the ability of engineering to affect society influenced students' decisions to study engineering, (b) examples that students used when describing the relationship between the engineering profession

and society, and (c) how feedback from society, the community, or the client should influence the engineering design process. The following three sections will address each of these issues, using representative quotes from students to highlight outlier and common comments. Together, these three themes provide insight into how engineering students view the relationship between the engineering profession and society.

(a) Does having an impact on society affect a student's choice to be an engineer?

> "I feel like engineering is a practical degree and that while, through other paths of study you could come out with a career where you're making changes and impacting the lives of human beings, I just feel like engineering is a pretty old, traditional, straightforward way of helping the community."
>
> - Susanna, Graduate Civil Student.

In the Semi-Structured and Timeline methods, students were asked directly what influenced their decision to come to engineering. Eight students spoke about how a desire to have a positive impact on society or to help others influenced their decision to become an engineer. Many students spoke about how they thought that engineering would give them the tools and knowledge to have a positive impact. One student talked about how wanting to invent a stair climbing wheelchair motivated her to become an engineer. Other students talked about how their specific discipline, usually Environmental Engineering, generally attracted people who "just really wanted to do good and to make a difference." While these views were not expressed by the majority of the students interviewed, it is notable that unsolicited, nearly one-third of the students spoke about serving societal needs as engineers. It could also have been the 'flavor' of EPRA that drew them to this subject; those students tended also to share that they see themselves as people drawn to serving others.

Two students spoke about how a desire to have a positive impact on society did not influence their views. Both of these students said this in response to questions from the ERPA tool, such as *I feel called by the needs of society to pursue a career in engineering,* in Survey-Focused interviews. One student, in talking about this survey question, said,

> "I did engineering because I wanted to do engineering, that's what I wanted to do. I didn't think about what society needed or how it affected me. And now, again, I think it gives me the tools to help, but it didn't affect my engineering choice."
>
> – Bradley, Graduate Civil Student

While Bradley asserted that it was not a motivating factor, he recognized that an engineer's tools could be used to help others. The majority of students mentioned being good at or liking math and science, or about knowing an engineer previously, as main motivators for studying engineering.

At the participating institution, graduating engineering seniors complete a survey about their perceptions of the program. One question asks them to identify from a list the single most important factor impacting their decision to major in engineering. From the Fall 2011 / Spring 2012 survey data, among 52 civil engineering student respondents, their most often cited reason

was *versatile career options* (33%), compared to only 10% who selected the *ability to contribute to society*. In comparison, among environmental (n=25), mechanical (n=75), and aerospace (n=37) engineering students the most widely cited factors were *the ability to contribute to society* (32%), *versatile career options* (43%), and *interest or talent in a particular field* (46%), respectively. *Ability to contribute to society* was selected by only 7% of mechanical and 8% of aerospace engineering majors. These results match the student interview data in this study, where no mechanical engineering students spoke about the ability to help society as a motivator, and half of the students who did consider service as a motivator were in environmental engineering, accounting for all of the environmental engineering students interviewed.

These results lead to interesting questions about students' motivations to become engineers and how the different disciplines are perceived by incoming freshman. Why are students who desire to serve society through engineering generally drawn to environmental engineering? Do the other engineering disciplines, specifically mechanical and aerospace, have the same capacity to serve society, but fail to 'brand' themselves in that way, therefore not attracting students who are motivated by a desire to help? Or is it that some disciplines are just inherently geared more towards having a positive impact than others and students know this, choosing their major accordingly?

Examining student perspectives serves as a reflection of the messages that they receive from the profession and from the educational system. The ability to have a positive impact on society motivated students to become environmental and civil engineers, more than it did mechanical or aerospace engineers. This suggests that the environmental and civil engineering disciplines are more associated with the ability to serve from outside of the engineering community, a message that is perhaps further enforced from within the disciplines. In talking about the mechanical engineering program, one student said, "…we're not really taught that you should look into helping people and to do that through engineering, we're not taught through that perspective. It's all about 'you're good at math, go do [engineering]', you don't care about building things, but you want money – it's super sad seeing that." That lack of a message in mechanical engineering regarding the ability to help others was discouraging and disappointing to this student.

(b) How students describe the relationship between engineering and society

> "When I think of serving the community, I see the bridge failing in Minnesota. The community needs a bridge, they have to have a bridge there so engineers have to put that in. But we're not performing community service because the community is paying for a particular utility to be placed in and we are providing our best quality, or to make sure that it's safe for as long as possible."
>
> – Trevor, Graduate Civil Student

Trevor touched on many of the common themes that students referenced to describe the relationship between engineering and society, including public safety, the built environment, ethics, and issues of sustainability, lifecycle, or longevity. Trevor explained the distinction between volunteerism, which he labeled as charity or donations, and service to the community, which he associated more with traditional engineering, such as building or repairing a bridge, in

exchange for payment. It is, in fact, precisely because an engineer is paid that negates the work from being "community service", even though the work provides a service to the community. Beyond the direct engineering solution (a bridge), Trevor also brought in further responsibilities of an engineer, including safety – "make sure that it's safe", ethics – "providing our best quality", and sustainability or longevity – "for as long as possible".

Seventeen of the 25 students mentioned public safety as a core societal obligation, giving remarks like "…to me that engineering is a profession is that we look into the details… to make sure that people are safe and that things work correctly for the long term", or simply that an engineer's obligation is to "build a bridge that's not going to collapse." Most students also made reference to the built environment to exemplify the ways in which engineers serve society. Other examples that students used including notions of environmentalism, energy efficiency, or simply that through the day-to-day work of an engineer, they are inherently benefitting society.

Missing from the conversations were discussions of civic responsibility for an engineer. One student talked about wanting to positively affect society by working on building code committees, and two other students highlighted an engineer's ability to educate the public about issues like hydraulic fracturing. None of the students, however, talked directly about the need for engineers to influence legislation or guide public policy. With only six of the 535 members of congress being engineers, and only 11 from Science, Technology, Engineering or Mathematics (STEM) backgrounds[17], it is not surprising that ideas of civic responsibility are lacking in the discourse surrounding the role of engineers in society.

(c) The role that society plays in engineering design

> "…the whole 'would I change a design based on society's needs', and I actually would not change my design… because I know the feeling of being like, I have this little technical way to do it, and it's really cool, and I think it's really smart, like clever, so I don't want to change that.' Like I'm going to fight you to the death to make sure that I get to keep this design. It's an interesting question, for engineers especially because we get really competitive about that… Yeah, and I feel like it's almost humbling yourself too, because you want to be on this level of your own, you want to be standing out for your creativity, for your difference. And then you're like, well, in reality it's not going to benefit anybody, it's just going to benefit my own ego. So it's probably not the best."
>
> – Thomas, Senior Mechanical Student

Thomas responded vehemently to a question from ERPA (*I would change my design if it conflicted with community feedback*), exerting his expertise as an engineer when it came to community feedback on a design. He identified a level of competitiveness in engineers as a main reason for his unwillingness to want to change, but also perhaps a larger desire to "stand out for your creativity, for your difference", in other words, a need for individualism in the profession that is achievable through the originality of your work. At the end, however, Thomas began to talk about the need for humility and to recognize that "it's not going to benefit anyone" if you ignore the community feedback and remain staunchly defending your design. Despite this

small turnaround at the end, Thomas did not express a desire to change his answer on his survey or to suggest that his core beliefs were any different than what he began with.

Thomas' perspective, however, was in the minority from these interview data. Six students talked about the importance of community involvement in engineering design, usually in response to this EPRA question. One student said, "…because if the project that you're doing for the people and they're not happy with it, then there's no point in doing it." A few students talked about the importance of ensuring that your work was actually desired by the community. Most of them referenced Engineers Without Borders or similar projects as past experiences where that was important. One student talked about a class trip to a construction site in a residential area:

> "…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, Senior Civil Engineer

Beau drew from a class experience to recognize how it was important for engineers, in this case during construction, to listen to the impacted community. The real constraints of "noise" and acceptable "construction times" were critical to consider and, as Beau recognized, were well within the purview of an engineer's responsibility. From the Survey-Focused interview method, a few students expressed some hesitation with their responses, not putting 'strongly agree' because they thought that there were limitations to how much they would change their design. One student said, "I don't know, because if they don't like it and for them to like it it's going to cost three times as much then I probably wouldn't change it because that's a little crazy to spend three times as much just to like it... if it still serves the same purpose and functions just as well…" This student recognized that there were other constraints, such as cost, that guide the engineering design process in addition to any community feedback.

Conclusion

Examining the ways in which students talk about the relationship between the engineering profession and society provides a lens through which to view the future of the profession and a reflection of how the engineering educational system is training students with respect to that relationship. Students who had a desire to positively affect society, and were motivated to pursue this passion through engineering, were generally drawn to environmental or civil engineering. Once in an engineering program, the message of being able to help through engineer may be lost, talked about by one student specifically in mechanical engineering. Additionally, the ways in which students talk about the interaction between engineering and society remained mostly at low level, bare minimum relationships of public safety and providing infrastructure. Few students talked about collaborative or co-creative relationships between engineering and society.

By talking about how engineers serve society simply through doing their job, students exemplified the belief described by Catalano "…that if we serve our employers faithfully and professionally, it (addressing issues of poverty and underdevelopment and environmental degradation) will somehow all work out in the end" [7] (p. 1). This supports a failure in the engineering community towards renewing the view of the engineering that Catalano calls for, one that focuses not only on public safety, but also on many "important issues of our time" such as poverty and sustainability. These interviews provided a reflection of the view of the engineering profession that students are learning through our current engineering educational system. It helps us to see how a desire to serve society draws some students to engineering, but that the continued message through courses are failing to teach students the importance of the relationship between the engineering profession and society, beyond the low threshold of public safety and infrastructure. In order to develop engineers with a broader understanding of the societal and cultural contexts in which they work, the students must first be guided to have broader views about how engineers and communities are to interact.

Acknowledgments
This research is supported by a 2011/12 Institutional Chancellor's Graduate Award for Excellence in STEM Education and by NSF Grant #1158863. Additionally, this work would not be possible if it weren't for the willingness of the student interviewees to participate and for their openness and honesty with the researchers about their views and beliefs.

Bibliography

1. NAE, Educating the Engineer of 2020: Adapting Engineering Education to the New Century, Washington DC: The National Academies Press, 2005.

2. ABET, "Criteria for Accrediting Engineering Programs Effective for Evaluation During the 2009-2010 Accredidation Cycle," ABET Engineering Accreditation Commission, 2008.

3. ASCE, "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, 2nd Edition," ASCE, 2008.

4. AAEE, "Environmental Engineering Body of Knowledge," American Academy of Environmental Engineers, 2009.

5. R. S. Weiss, Learning from Strangers: The Art and Method of Qualitative Interview Studies, New York, NY: The Free Press, 1994.

6. H. Rappaport, K. Enrich and A. Wilson, "Relation Between Ego Identity and Temporal Perspective," *Journal of Personality and Social Psychology*, vol. 48, no. 6, pp. 1609-1620, 1985.

7. G. Catalano, "Engineering and the Other America," in *Proceedings of the 2007 ASEE Annual Conference & Exposition*, Honolulu, HI, 2007.

8. K. M. Passino, "Educating the Humanitarian Engineer," *Science and Engineering Ethics*, vol. 15, pp. 577-600,

2009.

9. C. Titus, C. B. Zoltowski and W. C. Oakes, "Designing in a Social Context: Situating Design in a Human-Centered, Social World," in *Proceedings from the 2011 American Society for Engineering Education Conference and Exposition*, Vancouver, BC, 2011.

10. J. Schneider, J. A. Leydens and J. Lucena, "Where is 'Community'?: Engeinering education and sustainable community development," *European Journal of Engineering Education,* vol. 33, no. 3, pp. 307-319, 2008.

11. A. W. Astin, L. J. Vogelgesang, E. K. Ikeda and J. A. Yee, How Service Learning Affects Students, Los Angeles: Higher Education Research Institute, 2000.

12. J. S. Eyler, D. E. Giles, C. M. Stenson and C. J. Gray, "At a Glace: What We Know about the Effects of Service-Learning on College Students, Faculty, Institutions and Communities, 1993-2000: Third Edition," 2001.

13. W. Oakes, "Creating Effective and Efficient Learning Experiences while Addressing the Needs of the Poor: An Overview of Service-Learning in Engineering Education," in *Amercian Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Austin, 2009.

14. J. Duffy, L. Barrington and M. Heredia Munoz, "Is Service an Expected Part of the Engineering Profession?," in *Proceedings of the 2011 ASEE Annual Conference & Exposition*, San Antonio, TX, 2011.

15. C. West, J. Duffy, M. Heredia and L. Barrington, "Student Voices: Service-Learning in Core Engineering Courses," in *Proceedings of the 2010 ASEE Annual Conference & Exposition*, Louisville, KY, 2010.

16 N. Canney and A. Bielefeldt, "A Model for the Development of Personal and Professional Social Responsibility for Engineers," in *Proceedings of the Annual ASEE Conference and Exposition*, San Antonio, TX, 2012.

17 J. E. Manning, "Membership of the 111th Congress: A Profile," Congressional Research Service, Washington DC, 2010.