Designing For Stakeholders: Engineering and Applied Science Students Meet Stakeholders in a First-Year Undergraduate Introduction to Design Course

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Abstract

The Design I program at Colorado School of Mines introduces open-ended problem-solving and stakeholder engagement to all first-year engineering and applied science students. Since 2015, this program has implemented a variety of stakeholder-related deliverables for the approximately 600 students who take the course each semester. One of the learning objectives for the course is to teach students to seek out and draw on the perspectives of people who have a stake in the problems they choose to define and address. In order to help engineering students build skills and confidence in these key areas, Design I challenges them and supports them as they engage with team-based open-ended problem solving. Stakeholder engagement and related skills are regarded by many educators and practitioners as essential to engineering, but presenting these topics to students in ways that seem integrated into their technical training is not a simple undertaking. Stakeholder work can pose particular challenges related to practical project management, to conceptual work, and to the way that students understand themselves. In this paper, we present preliminary findings related to faculty and student assessments of challenges related to the program's existing stakeholder engagement curriculum. The research that this paper describes is a baseline assessment of challenges students experience related to the goals of this course and the development of skills that will support their ongoing development as thoughtful engineers with implications for future program development in support of these goals.

Introduction

The Design I program at Colorado School of Mines introduces open-ended problem-solving and stakeholder engagement to all first-year students. Since 2015, this program has implemented a variety of stakeholder-related deliverables for the approximately 600 engineering and applied science students who take the course each semester. One of the learning objectives for the course is to teach students to seek out and draw on the perspectives of people who have a stake in the problems they choose to define and address. This provides the practice that students need to become more skilled in the process of technical problem solving as it is practiced in the workplace. This course is designed to build students' confidence in applying fundamental problem-solving concepts in order to solve complex, open-ended problems.

One of the learning objectives for the course is to teach students to seek out and draw on the perspectives of people who have a stake in the problems they choose to define and address. In engineering education, stakeholder engagement is part of project-based learning [1]. While serious encounters with stakeholders have been a topic of increasing centrality within technical fields [2] [3] and understood to be core to the training for engineers and applied scientists [4] [5], this work is by no means simple. Further, as these activities require skills students may neither come to college familiar with nor practice in multiple courses, courses like Design I experience significant pressure to both cover a great deal of ground and do so in ways that are accessible and appropriate for students completely new to these areas.

Interacting and making the most of encounters with humans is one important but difficult component of this project-based design learning. Social research is complicated by student anxieties, the vicissitudes of schedules, communication challenges, and analytical work of making whatever they learn from someone relevant to their project.

Helping students develop effective research and engagement strategies, enact them, and then integrate what they learn into their technical work is a matter for practical concern, as indicated by, for example, the development of such multi-year, cross-disciplinary NSF "Transforming Undergraduate Engineering Education" (TUEE) initiative [6]. Further, if we understand technical artifacts to have politics [7] and to reproduce the conscious and unconscious priorities held by their designers, then giving students robust tools to critically consider the implications of their designs has broad implications. Courses like Design I give students tools to build insights and skills that may help them make more thoughtful and inclusive choices [8]. Engineering educators and researchers suggest that design can be a crucial site for thinking about how "technology development might be directed as wisely and fairly as possible" [9] and engaging with issues of social justice [10].

While orienting design decisions around real human beings is increasingly recognized as important in engineering education circles [11], doing so deeply and productively can be challenging for students. For example, engineering education researchers have identified student challenges related to what we consider more *conceptual* issues in problem scoping [12] and effectively integrating what they learn from stakeholders into designs [13]. There are other reasons that working with stakeholders may be difficult related to issues as straight-forward as recruiting people to participate in their projects, scheduling meetings with them, and managing interactions in those meetings effectively. While the distinction between these issues and those related to the use of information may sometimes be hazy, we find it helpful to refer to research in user experience that addresses "practice-level struggles" [14] [15] to consider how we are asking our students to undertake *practical* as well as *conceptual* challenges when we ask them to work with stakeholders.

We address Design I students' encounters with and attempts to learn from people as part of their team-based semester-long design project, in an effort to improve the teaching tools and student outcomes. We draw on three sets of data about how students currently engage with stakeholders in the context of this course: 1) classroom observations, 2) semi-structured interviews with faculty, and 3) surveys of students. We identify a set of challenges that students may be experiencing in their work with stakeholders, and consider next steps based on these findings. In doing so, we take up a research topic that is crucial to supporting student learning in ways that support inquiry into what Zoltowski, Oaks, and Cardella have called "the qualitatively different ways in which students experience and understand human-centered design in the context of 'designing for others.'" [11] By engaging faculty and student perspectives in this way, we can identify the challenges that are relevant to their experiences of Design 1 and then prioritize further pedagogical interventions.

Background

The development of the Design I curriculum happened in the context of large-scale trends in industry needs, but it was also built with careful attention to the practical, grounded experiences and insights of a Colorado entrepreneur. As a training psychiatrist, Paul Polak learned that he could not diagnose his patients accurately without visiting their homes and workplaces to better understand their symptoms in context. He founded the Southwest Denver Community Mental Health Services Inc. in 1971, which in turn influenced working models of community-based care for severely mentally ill clients nationally and internationally [16]. As founder of International Development Enterprises (iDE) in 1981, he created a new model of international aid based on deeply understanding those intended to lift out of poverty, and leveraging existing markets to sell rather than donate appropriate technology to base of pyramid markets.

In 2015, Design I shifted from offering students neatly constrained problems to solve, to what Rittel and Weber called "wicked problems" [17] [18]. At the same time, the program introduced large scale simulations for the students to take part in in order to generate empathy with the people for whom they were designing. By fall of 2016, the course began to develop user centered design-inspired curriculum modules focused explicitly on stakeholder engagement, including scaffolded assignments to help students:

1. Identify stakeholders and analyze their relevance to the problem.
2. Interview Subject Matter Experts (SMEs) and other stakeholders of the project to understand the problem.
3. Analyze the problem from a user's and stakeholder's perspective.
4. Refine ideas through qualitative and quantitative justification with respect to requirements, constraints, novelty, and stakeholder needs.

In spring 2017, Polak served as Executive in Residence in the Division of Engineering, Design and Society at Colorado School of Mines to guide faculty and staff on how to incorporate end user information into routine design problem definition and solution processes. Today, this course, which exposes students to both user empathy and stakeholder engagement [19], has the following learning objectives:

1. Identify, breakdown, and define open-ended problem(s).
2. Research the context and background of problems and solutions, through a variety of scholarly and authoritative sources.
3. Design solutions through cycle of testing, refining, iterating, and feedback.
4. Equitably contribute to team efforts from start to end on a collaborative project.
5. Apply common workplace practices, tools and software in a semester long team project, including: project planning tools, team management tools, tools to generate solution alternatives, decision analysis methods, risk analysis methods, and value proposition analysis / baseline comparison.
6. Communicate, pitch, and justify your design decisions in a variety of formats.
7. Use field sketching to communicate ideas visually to colleagues and stakeholders and to develop ideas through iteration.
8. Use standardized engineering graphics conventions as applied to technical sketching and computer-aided design/solid modeling software to communicate formalized design ideas.

Students are divided into 5-person teams to understand, define, and then develop and refine

solutions for an open-ended problem shared across the 25 or 26 sections of Design I. In the fall semester of 2018, the theme was apocalypse defense, and students were directed to consider disasters of all kinds before focusing on their chosen challenge area.

Grappling with messy problems like this forces the students think creatively. To help them define their problems and refine their planned solutions, as well as to give them experience with aspects of engineering and applied science that they may not learn in other lower or mid-level classes, they are directed to reach out to a variety of people they identify as stakeholders.

Scaffolded assignments ask students to identify stakeholders and subject matter experts and analyze their relevance to the problem, interview subject matter experts and other stakeholders of the project to understand the problem, and analyze the problem from users' and stakeholders' perspectives. Faculty, many of whom have significant experience in industry, act as "managers" and guide students through this work, offering insights from their work as practicing problem solvers as well as their expertise as educators.

Data

Observation

The first author observed classes and participated in several different ways: She sat in on 4 75-minute-long class meetings in early stages, during which students were beginning the stakeholder research process. Although the first author visited a different session each time, she noted that in all of them students seemed full of energy and engaged in class but some talked about being very intimidated by work with subject matter experts, users, and other stakeholders. They were confused about where to begin. Some spoke about worry or confusion when asked about stakeholder work.

When the first author was identified as a subject matter expert by one group of students, she got a close-up view of the challenges that some students might have with interviewing. The student group who spoke with her had some trouble in designing their interview questions, which had been scoped in such a way that they were unlikely to get any information that would be useful to them. For example, the first author, a social scientist and expert in social practices regarding earthquake risk mitigation, was asked to describe structural effects of various forms of earth motion on the built environment, which is a better question for a civil engineer. She was able to talk about the social conditions of vulnerability to these hazards and about public understanding of seismic risk, but students seemed uninterested in this information. Instead, they approached this interview as a source of facts that they had already decided would be important for a design that they already had in mind even though their faculty had encouraged them to try not to start designing until they had completed interviews. The first author took extensive notes on the experience to refer to while writing this paper.

When the students presented their final designs at the end of the semester, the author served as a judge for two classes of students, talking with a total of 10 groups in the process. While the students presented fascinating and creative concept solutions, there was also a wide variety in how pertinent the stakeholders identified by students were to their projects and how well the students could describe how those stakeholders informed their project work. In this small

sample, the first author spoke to two groups who did truly excellent work and communicated about it clearly, but noted that others seemed to have a much more difficult time. She took careful notes of their responses to questions regarding stakeholders and discussed her observations with other faculty members serving as judges in order to validate her observations.

The second author, having guided 30-40 teams through their problem-solving experiences throughout the life of the program, found these observations to be in keeping with her own experiences. She has noted that the majority of students show extreme discomfort with their stakeholder engagement assignments, and that many produce work products at a lower level than she understands them to be capable of, even by the end of the semester. She often sees a resistance to "pivoting" to new ideas in the face of stakeholder information without forceful intervention.

Faculty Interviews

Interviews with faculty responsible for teaching Design I supported these observations. The first author asked 15 of the 22 total instructors to talk about their students, focusing their attention particularly on challenges in short (10-20 minutes long) semi-structured and open ended interviews. In these interviews, faculty responded to prompts such as "what parts of working with stakeholders do you think your students struggle with?" by describing their ways of thinking about students and teaching. These responses were diverse, and reflected on their own learning experiences, and on the different capabilities of students who came through their classroom and their roles supporting students taking on challenges that might be more difficult for some than for others. Faculty showed commitment to helping students, and did so with the understanding that some students experienced more challenges related to course topics than others did.

In the context of these interviews, they described the challenges that some of their students face with stakeholders in a number of different ways, recorded in Table 1, below. These items are a tally of challenges that students may face, and should not be understood of a catalog of challenges that all or even a majority of students that they work with experience. The items were reviewed by the second author, one graduating student, and finally submitted to all faculty members in a large meeting context to make sure that the statements were written in such a way as to make sense to as much of the Design I community as possible and that no points were lost or mis-represented. The first author placed them in categories of "conceptual" if they were issues related to understanding how to have the best and most productive interactions with stakeholders; "personal" if they were related to student identities, qualities, or preferences; and "practical" if they were straightforwardly related to issues like time management, access, skills.

Table 1. Student Challenges Identified by Faculty

Challenge	**Type of Issue**
Selecting questions to ask stakeholders	conceptual
Identifying the right stakeholders for the problem	conceptual
Integrating stakeholder feedback into design	conceptual

Holding off on defining the problem	conceptual
Knowing when to stop focusing on collecting stakeholder input	conceptual
Understanding why non-technical stakeholder options should be included	conceptual
Being an introvert	personal
Dislike talking to people	personal
Worrying about saying the wrong thing to a stakeholder	personal
Being right brained, not left brained	personal
Frustration at not achieving expected performance level when working with stakeholders	Personal
Making initial contact with stakeholders	practical
Scheduling time to talk to stakeholders	practical
Getting technical experts to answer the questions asked of them	practical
Using a professional style of communication with stakeholders	practical
Lack of response from stakeholders	practical
Time frame of the course and design process	practical
No local friends and family to help identify and recruit stakeholders	practical

Student Survey

In the final weeks of the course, three classes out of 26 were selected to be surveyed to reflect 1) the variety of faculty backgrounds, which incorporate industry experience, advanced academic preparation in engineering fields, and long involvement in design (a class taught by each type of faculty was selected) and 2) the time the courses met (classes that met during the morning or early afternoon were selected, so that student athletes with afternoon practice times could be represented). An anonymous survey was distributed in these classes, and students completed it in approximately five minutes.

The demographic breakdown of survey participants is relatively representative of those at Colorado School of Mines. 70 students were surveyed, but 2 did not complete the whole survey, so their responses were discarded, leaving us with 68. All students were in their first or second year at the school. Information was collected on gender, age, and transfer status because authors hypothesized that these, in particular, might be related to different levels of comfort with the conceptual, personal, and practical challenges related to stakeholder work.

Table 2. Student Demographic Table

Gender		**Transfer Status**		**Age**	
men	women	transfer	non-transfer	≤19 years old	≥20 years old
40	28	16	52	48	20

We developed a list of kinds of work that students were likely to encounter in future engineering and applied science careers and likely to have discussed with their faculty, including apparently-technical work, work that was explicitly social in some way, and activities or goals that could be considered to be either. We then asked students what aspects of these they were interested in doing, instructing them to choose as many as they liked.

Table 3. Student Interest in Aspects of Engineering and Applied Science

Aspects of Engineering and Applied Science Work	**Number of Students Noting Interest**
Helping Other People	47
Working in the Field	45
Testing and Iterating	43
Building Things	42
Making Your Mark on the World	39
Working in Teams	37
Project Management	36
Analyzing Things	34
Presenting Your Ideas to Others	25
Doing Background Research	25
Working with Clients	22
Working in a Laboratory	21
Drawing/Graphical Communication	21
Working at a Computer	20
Stakeholder Engagement	8
Writing Reports	6

After this course, most students indicated commitment to “Helping Other People” (47/68) and “Testing and Iterating” (43/68) –both related to course learning outcomes noted above. The wide spread of responses indicates how diverse the group of students might be. Many of the topics that a substantial number of students report explicit interest in (including “Working in Teams,” “Project Management,” and “Working with Clients”) are recognized as essential to engineering profession but nonetheless sometimes described as if they are outside the scope of engineering work [20]. It is worth noting that relatively few students expressed excitement about “Stakeholder Engagement” (8/68). It is possible, though, that student indications of interest in topics related to course learning outcomes like “Stakeholder Engagement” as well as “Working in Teams”, “Project Management,” and “Working with Clients” would have been much lower if students had been asked before they participated in the course.

Overview of Responses: Students Are Challenged

In the survey, we learned faculty are not incorrect in noticing that some students find stakeholder engagement portion of the class challenging. Students also indicate that they experience this work as challenging. When asked to respond to an open-ended question and characterize their experience with stakeholder engagement, many of the students (25/68) had mixed or neutral things to say, indicating that many saw this aspect of their coursework as both difficult and rewarding. Those students who shared more negative comments detailed practical challenges.

These responses can help us understand how students experienced stakeholder engagement, and the challenges that they bring up should be understood in that context; they are not only indications of struggles but of engagement. These were, of course, highly varied.

A statement focused on rewards might focus on enjoyment and ease:

> *The stakeholder engagement process was okay for me, most people I talked to were very willing and excited to talk and answer questions.*
>
> *It was fun to get to go out and talk to people about things they're passionate about*

A mixed or unclear statement might contextualize challenges, weigh them against benefits, or offer a commentary that was both easy to understand and hard to classify:

> *It went fairly smoothly for me, but some stakeholders didn't respond or weren't flexible with the group members*
>
> *It was hard to come up with the right questions to ask stakeholders and get a response from them, but we got good input from the stakeholders that did respond*
>
> *It is a bit stressful but in the end is very beneficial and helped quite a bit*
>
> *Mind boggling experience*

A statement focused on challenges generally highlighted personal anxieties or practical struggles, though a few articulated general frustrations rather than thoughtful evaluations:

> *I found engaging with stakeholders difficult due to a feeling of intimidation.*
>
> *Hard to find stakeholders that knew about our topic.*
>
> *Mostly just didn't have enough time to get responses from stakeholders before we had to move forward with the project*
>
> *Slow, unsuccessful*

Table 3. Students Characterize their Experiences with Stakeholder Engagement

All Rewards	**Mixed or Unclear**	**All Challenges**
12	25	20

We also presented students with the list of descriptions and explanations of challenges developed through faculty interviews (see Table 1). We gave them the following prompt: "*Below are a list of ways that some people describe and explain the challenges of working with stakeholders. In Cornerstone this semester, which of these do you think made working with stakeholders challenging to you?"* and asked to choose all that applied to them. All 68 students indicated that they were struggling with something on that list. Students indicated that they had struggled with every challenge that faculty identified. On average, students selected 4.3/18 challenges, indicating that no one experienced stakeholder engagement as entirely easy, but no one was experiencing every one of the diverse struggles that faculty identified.

Table 4. Student Perceptions of Challenges

Challenge	**Number of Students Noting Challenge**	**Type of Issue**
Making initial contact with stakeholders	33	practical
Lack of response from stakeholders	29	practical
Selecting questions to ask stakeholders	28	conceptual
Scheduling time to talk to stakeholders	27	practical
Time frame of the course and design process	27	practical
Identifying the right stakeholders for the problem	20	conceptual
Being an introvert	17	personal
Integrating stakeholder feedback into design	15	conceptual
No local friends and family to help identify and recruit stakeholders	15	practical

Holding off on defining the problem	14	conceptual
Dislike talking to people	14	personal
Getting technical experts to answer the questions asked of them	14	practical
Knowing when to stop focusing on collecting stakeholder input	11	conceptual
Using a professional style of communication with stakeholders	9	practical
Frustration at not achieving expected performance level when working with stakeholders	9	personal
Worrying about saying the wrong thing to a stakeholder	8	personal
Understanding why non-technical stakeholder options should be included	4	conceptual
Being right brained, not left brained	1	personal

Relatively few students identified with statements referring to emotions or personal characteristics. The most commonly listed personal challenge, "being an introvert," was noted by less than 1/3 of respondents (17/68). Instead of personalizing their challenges, students tended to identify practical issues related to managing schedules, and, to a lesser extent, conceptual issues related to interview design and stakeholder selection. We find this encouraging, as it is much easier for a student to learn interview design skills than to start to identify as an extrovert.

While we hoped that the diversity of responses would allow us to produce profiles of students who struggled with one aspect or another of stakeholder work, we found no statistically significant correlations with other student characteristics after performing student T-test against gender, age, transfer status, types of engineering and applied science work that interested the students, and against reporting primarily positive or negative responses to open ended questions.[1]

Discussion and Conclusion: How Can We Support Students?

Observational data, faculty reports, and student assessments indicate that students in Design I may not be overwhelmed by the challenges of stakeholder engagement, but that no one finds it a thoroughly easy process. Struggles can encourage student engagement but may also lead to sub-optimal engagement in the classroom. Many of the areas that students note that they struggle with might be understood as an opportunity for students to identify nontechnical operations related to design practice as crucial skills. Making contact with stakeholders, project management, developing thoughtful questions, and integrating stakeholder insights into designs

[1] Student T-test was selected as appropriate because of the relatively small sample size of students surveyed here and because it facilitates comparisons between two populations (male students vs female students; students aged 19 and under vs. students aged 20 and older; transfer students vs non-transfer students). The lack of statistically significant correlations would have been found even if we had set P at .05, but the Bon Feroni correction to account for multiple tests, which would require an alpha level of .01, is more appropriate here.

are key aspects of professional practice that may be under-emphasized in technical curricula [20].

Design I contains a number of assignments developed to help students strategize their engagement and develop these skills. Faculty coach students through the stakeholder engagement and design process. Some faculty even recruit their own contacts to act as stakeholders for student teams in order to make recruitment and interviewing as uncomplicated as possible. Through these mechanisms, our students have resources provided by thoughtful scaffolded assignments and the support of experienced and empathetic instructors who are committed to helping them learn and remember when they, themselves, were learning similar skills. Yet still, empirical evidence indicates that some students are struggling.

In the future, classroom instruction will experiment with assignments and lessons focused on the practical and conceptual issues related to stakeholder work that the most students indicated that they found challenging (see Table 5). This might include lessons that model good and bad interview question development, that focus on question staging, and stakeholder identification activities that deal with themes of selection and sampling. For all that these skills may not be taught in much mainstream technical curricula, they are the topic of significant attention in other fields. Tools borrowed from the social sciences (see for example [21]) may support struggling students in these higher priority areas.

Table 5. Top Challenges Perceived by Students

Type of Issue	**Challenge**	**Number of Students Noting Challenge**	**Type of Issue**
1	Making initial contact with stakeholders	33	practical
2	Lack of response from stakeholders	29	practical
3	Selecting questions to ask stakeholders	28	conceptual
4	Scheduling time to talk to stakeholders	27	practical
5	Time frame of the course and design process	27	practical
6	Identifying the right stakeholders for the problem	20	conceptual

Students in this course should struggle —we understand that struggling is part of learning [22]. One Design I student called stakeholder work a “mind boggling experience”, which may be a positive thing. Important learning opportunities can happen when students’ minds “boggle”. In this paper, we have identified particular challenges that may be associated with stakeholder work. The research that this paper describes is the first step in a process that will next entail identifying, crafting, and evaluating new tools, such as those proposed above, to support their ongoing development as thoughtful engineers and applied scientists. Further research and analysis would be necessary to produce profiles of students that might struggle in one way or another, which might enable us to offer differentiated learning tools for the various student

segments.

References

[1] D. Goleman. *Working with Emotional Intelligence*. London: Bloomsbury Publishing,1998.

[2] S. C. Stewart, "Interpreting Design Thinking," *Design Studies*, vol. 32, no. 6, pp. 515–520, 2011.

[3] L. Kimbell, "Rethinking Design Thinking: Part II," *Design and Culture.*, vol. 4, no. 2, pp. 129–148, 2012.

[4] M.J. Reimer, "Integrating Emotional Intelligence into Engineering Education." *World Transactions on Engineering and Technology Education*, vol. 2, no. 2, pp. 189-194, 2003.

[5] D. Mcdonagh. "Empathic Design: User Experience in Product Design." *The Design Journal*, vol.7, no. 3, pp. 53-54, 2004.

[6] L. DiCarlo, "Teach Your Children Well: (How and) Why Design Anthropology Speaks to Our Students," *Journal of Business Anthropology,* vol. 7, no 2, pp. 268-278, 2018.

[7] L. Winner, "Do Artifacts Have Politics?" *Daedalus*, vol. 109, no. 1, pp. 121-136, 1980.

[8] C. Miller and E. Hitch, "Design Anthropology: An Introduction to the Themed Issue," *Journal of Business Anthropology,* vol. 7, no. 2, pp. 157-162, 2018.

[9] D. Nieusma, "Alternative Design Scholarship: Working Toward Appropriate Design," *Des. Issues*, vol. 20, no. 3, pp. 13-24, 2004.

[10] D. Nieusma and D. Riley, "Designs on Development: Engineering, Globalization, and Social Justice" *Engineering Studies* vol. 2, no. 1, 2010.

[11] C. Zoltowski, W. Oakes, and M. Cardella, "Students' Ways of Experiencing Human-Centered Design," *Journal of Engineering Education*, vol. 101, no. 1, pp. 28–59, 2012.

[12] C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg, and J. J. Saleem. "Engineering Design Processes: A Comparison of Students and Expert Practitioners." *Journal of Engineering Education*, vol. 96, no. 4, 359 –379, 2007.

[13] W. A. Sugar, "What is So Good About User-Centered Design? Documenting the Effect of Usability Sessions on Novice Software Designers," *Journal of Research on Computing in Education*, vol. 33 no. 3, 2001.

[14] J. B. Scott, "The Practice of Usability: Teaching User Engagement Through Service-Learning," *Technical Communication Quarterly*, vol. 17, no. 4, pp. 381–412, 2008.

[16] P. R. Polak and M. W. Kirby, “A Model to Replace Psychiatric Hospitals,” *Journal of Nervous and Mental Disease*, vol. 162, no. 1, pp. 13-22, 1976.

[17] H.W. Rittel & M.M. Webber, “Dilemmas in the General Theory of Planning,” *Policy Sciences*, vol. 4, no. 2, 1973.

[18] R. Buchanan, “Wicked Problems in Design Thinking,” *Kepes*, vol. 8, no. 6, pp. 7–35, 2010.

[19] L. Light and L. Mitchell, “Increasing Student Empathy Through Immersive Stakeholder Engagement Experiences in First Year Design Education,” American Society for Engineering Education, Seattle, WA, June 2015.

[20] W. Faulkner, “‘Nuts and Bolts and People’: Gender-troubled Engineering Identities,” *Social Studies of Science*, vol. 37, no. 3, pp. 331-356, 2007.

[21] H. R. Bernard, *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, 4th ed. Maryland: AltaMira Press, 2005.

[22] M. Pavelich and W. S. Moore, “Measuring the Effect of Experiential Education Using the Perry Model,” *Journal of Engineering Education*, vol. 85, no. 4, pp. 287-292, 1996.