

Women Thriving in Engineering: Listening to and learning from women who flourish in undergraduate engineering project teams

Rick Evans, PhD
College of Engineering
Cornell University
Ithaca, NY, USA
rae27@cornell.edu

Jia G. Liang, PhD
Educational Leadership
Kansas State University
Manhattan, KS, USA
gliang15@ksu.edu

Mojdeh Asadollahipajouh, PhD, PE
Civil and Environmental Engineering
University of Nebraska–Lincoln
Lincoln, NE, USA
mojdeh.pajouh@unl.edu

Stacey Kulesza, PhD, PE
Civil Engineering
Texas State University
San Marcos, TX USA
sekulesza@txstate.edu

Abstract—Our work-in-progress research offers a distinctive focus and methodology. We focus is on women who are thriving in undergraduate engineering student project teams. Our methodology adopts a feminist, activist, interpretivist perspective using a multi-case study, critical sampling approach that attends to small numbers in order to learn from small numbers. Our early results suggest that these women are thriving because they experience joy in developing and applying engineering expertise, in knowing what and knowing how in response to real, tangible and challenging problems. They report that the experience is exciting, self-rewarding and self-defining. Such research can potentially change the negative discourse regarding women and engineering education with a discourse that is more welcoming and inclusive.

Index Terms—Gender, Project Teams, Engineering Education

I. INTRODUCTION

For the last 40 years the aggregate number of women receiving bachelor degrees in engineering in the US has remained approximately 20% [1]. The current research has used limited research rationale and theories, and included limited types of participants' roles in only a few types of research settings [1], [2]. Such research has been characterized as lacking diversity, e.g., ignoring intersectionality theory, overwhelmingly quantitative, homogeneous and standardized. Although it has established that the educational institutions in which women sought inclusion are themselves gendered, raced and classed, the aforementioned type of research has had little impact on implementing change [3], [4]. Previous research may have created a negative discourse regarding engineering education and thereby actually deterred women from viewing engineering as a viable educational and career path. Our research is distinctive in focus and in methodology. Our focus is undergraduate women students who thrive in engineering project teams and our methodology attends to small numbers in order to learn from small numbers [3], [5].

If we want more engineers and to realize a more inclusive and welcoming engineering community, then we need to learn more about the processes of becoming an engineer [4], [6]. We

need to learn more about how, in our case, women come to think of themselves as engineers. We need to learn more about how they perform their engineering selves, and how others come to identify them as engineers [7].

Our approach is guided by a feminist, activist and interpretive lens, one that is grounded in women's experience, gives voice to those women whose experience is sometimes hidden, and encourages emancipatory praxis [8]. Such a perspective is often referred to as a standpoint epistemology. According to Sprague [9], standpoint epistemology argues that all knowledge is constructed from a particular position and that what the knower can see is shaped by the location from which that knower's inquiry begins. Specifically, she posits four guidelines for conducting research using a standpoint epistemology:

- 1) Focusing on everyday life as everyday actors know it;
- 2) Acknowledging the partiality of all interpretations of experience;
- 3) Initiating and maintaining dialogue across differences;
- 4) Making things possible through empowerment [9].

Our research adopts a multiple, layered qualitative case study design in order to learn more about a specific, bounded system – women who are thriving in undergraduate engineering student project teams [10]. Engineering student project teams are extracurricular teams that work towards a competition, service project, or for a client. We are investigating these women at three different institutions: A private college of engineering located in the northeast, a state college of engineering located in the midwest, and a designated HSI state college of engineering in the west. Each institution represents a case and, within each institution, each woman undergraduate student stands as a unit of analysis. Such a design allows us to observe the commonalities and the differences both across undergraduate women students and across institutions.

The case study method offers two advantages that are significant to the project. First, the knowledge generated by case studies is concrete and context dependent [11]. Given the importance of the everyday life as everyday actors know

it in standpoint epistemology, attending to what is concrete and context-dependent about these women's experiences is essential. Second, case studies are particularly useful in the heuristic identification of new variables and potential hypotheses that might help us to better understand and explain the phenomenon we are studying [12]. As the familiar explanations, e.g., mis-socialization, fail to account for these women's significant participation, entertaining the possibility of new variables and potentially more explanatory hypotheses is critical.

Our research approach has much in common with positive psychology and human thriving. Positive psychology represents a "shift from an emphasis on pathology toward positive human functioning" [13, pp. 167]. We are interested in changing the negative discourse that permeates discussions of women's participation in engineering for an alternative, more positive discourse of empowerment. Such an alternative discourse highlights terms often used in reference to thriving – development and performance [14], [15], motivation [16], challenge and resilience [17]–[19], trust and support [20], [21]. In particular, positive psychology suggests that we look for personal enablers and contextual enablers, factors related to the individual and the environment respectively that encourage thriving [13].

II. OUR UNIQUE RESEARCH METHOD

A. Selection of Participants

We select participants purposefully (i.e., a critical sampling strategy [22]) using the following criteria: a) undergraduate women who have participated on engineering project teams for 2-3 years and, if possible, are in leadership positions; b) participants who consider themselves to have had positive experiences on project teams (certainly not only positive experiences); and c) participants who are willing to share those experiences. We attempt to include women from all three types of project teams: competition, service and client-serving. We expect a sample size of 25-35 students.

We are aware that the predominate number of women engineers identify as racially white. Because we are devoted to diversifying the pathways into engineering, we have and will continue to identify and recruit women of color or women who occupy other minoritized sociopolitical spaces (e.g., nationality, age, lingual, social class). Our critical sampling approach allows us be cognizant of and responsive to these socially constructed and fluid categories. In addition, we have adopted the integrative model of intersectionality: one that considers each of a person's subordinate identities to interact holistically, suggesting that people experience these identities as one [23]. This perspective leads us to create a sub-codebook for women of color or other women occupying minoritized spaces separate from yet still included within the overall codebook for those who identify as white. We expect to recruit a majority of women of color from two of the institutions. In addition, two of the PIs are women of color.

A general email is being sent to all women participating in undergraduate student project teams. The email contains a

brief description of the study and its purpose along with a request for volunteers. The purpose of the email is not only to make our request, but also to ensure participant agency and to foster a diverse participation of volunteers. Ensuring participant agency is consistent with our feminist, activist and interpretive perspective. Fostering diversity allows us to acknowledge the partiality of the participants' interpretations of their own experiences, particularly when compared with the experiences of others. We also believe that it supports participant retention because their decision to participate is their own. We consulted with the Institutional Review Boards (IRBs) of the participating institutions prior to contacting volunteers to confirm that we adhere to all appropriate IRB protocols.

B. Interview Sequence

Each participant is asked to agree to a sequence of three interviews, each lasting approximately one hour. The three interviews are described below. The researchers at each site are expected to carry out and track the progress of the project, i.e., data collection, analyses, project journaling, as well as convene regularly as a team to ensure transparency, consistency, and triangulation for project quality purposes. Each interview is inductively analyzed using NVivo software.

1. *Life History Interview.* A life history interview serves as an important starting point in that it allows researchers to attend to the ways the undergraduate women in engineering narrate their lives [24]. It provides researchers access to the lives interpreted and made textual by the women who have lived them. Furthermore, it provides researchers with the background of how these women understand themselves to have selected engineering and to have chosen to participate in undergraduate engineering student project teams.

2. *Individual Learning Journey Interview.* Learning journey interviews attempt to capture the learning process experienced during time [25]. The aim of such interviews is to encourage the interviewees to reflect on and be able to relate to learning aspects of their experience as project team members [25]. The women are asked to begin with when they first learned about and/or became interested in project teams, and then to describe their experiences as team members. We are interested in understanding why the women have both opted in and committed themselves to these project teams.

3. *Photovoice Interviews.* Photovoice is a form of participatory action research that places participants behind a video camera, encouraging them to document relevant and important elements of their lives (in this case, of their lives in project teams) in their own terms [26]. Students are asked to become ethnographers of their own experience, to film the routines and events that they believe are important for researchers to understand. Then, in a third interview, we ask participants to assign meaning to the videos – help us to see and understand what they considered relevant and important. Our aim is to learn more about the positive experiences of these women as identified and explained by the women themselves.

We argue that our research approach gives voice to the volunteer participants – adheres to the four guidelines of standpoint epistemology. First, case studies and the interviews in sequence focus on the everyday life as everyday actors know it. Critical sampling across three different institutions both acknowledges the partiality of any one participant’s experience in effect not only initiating and maintaining a dialogue across difference, but also necessitating that dialogue. The sequence of interviews empowers these women to tell their stories of thriving, to claim their identities, indeed their competencies and expertise as engineers. We believe that the more that women can claim their identities, their competencies and expertise; the more they will feel empowered and powerful. Finally, emancipatory praxis will not result from calling out institutions as “gendered, raced and classed” [3], [4]. It has not done so for over 40 years. Emancipatory praxis is more likely to result when those who suffer from gender, race and class bias, can claim to thrive, can claim doing engineering, and can claim being engineers. In what follows, we report the early findings observed from the first two types of interview data. PhotoVoice interviews are scheduled to occur in fall, delayed due to COVID circumstances.

III. RESULTS AND DISCUSSION

A. Personal factors

The women seem to have been members of families in which the parents were involved in their children’s lives, but not so involved as to direct those lives. They were generally encouraged to explore new experiences and were supported, both with parental time and resources, for those explorations. The families were gendered in that there were understood male and female roles. As girls, they were aware of those roles. However, the roles did not seem to serve as a prohibition. They were allowed, even encouraged, to assume alternative roles. There were gender differences among siblings, and those differences were both tolerated and celebrated. Finally, failure was not only allowed, but often understood to offer an opportunity for “getting better” and there was tangible parental support for getting better. The women understood that even if they experienced difficulties elsewhere, there would always be acceptance and reassurance at home.

Outside of the family, their gender socialization was what one might expect. Again, there were understood male and female roles. However, unlike in the family, assuming alternative roles sometimes came with consequences. Indeed, what seemed most disturbing to these women were the limitations that these gendered roles placed on them, e.g., girls are not interested in understanding how things work; or how those limitations were assumed by others to be true, e.g., girls are not good at math. The women we interviewed experienced both kinds of role limitations. And, while all the women growing up were comfortable in their normative gendered roles, they also bristled, some less and some more, when they experienced those limitations.

School represented an opportunity to explore interests, to learn by doing new things – less in relation to the curriculum

(although occasionally there were engaging courses) and more in terms of what might be considered extra-curricular activities, e.g., clubs or competitions. There was always “something to do.” And doing these somethings allowed them to explore, to better understand their capabilities and interests, to gain confidence, to develop greater self-efficacy and a sense of belonging in relation to their peers. This seemed quite important for positive identity formation. It was also important that what they explored or did was challenging and required a commitment. It was sometimes the case that the challenge and required commitment were actually more engaging than the activities themselves. It was not unusual, for example, that once a certain level of competence was realized, the women participants would engage in another challenge, often demanded high commitment. Those engagements that endured often became identity-defining.

Few of these women, at least before college, thought of engineering as a career choice. Their decision to pursue an engineering education was made after matriculation. For most, they learned about undergraduate project teams either on campus visits or shortly after they arrived on campus. Once they learned about project teams, they were not only interested, but quite determined to participate.

B. Gendered institutional and project team context

At one institution, undergraduate student engineering project teams are hard to get into. They have a very low acceptance rate of new members. Consequently, mere acceptance merits a certain status. The women interviewees reported feeling “lucky” that they were chosen. At the other institutions admission was not so competitive. At all the institutions, new members are generally assigned to one of a number of sub-teams. Each sub-team has a team lead. New members understand that they are to follow the directives of that team lead. The structure of the teams and sub-teams is hierarchical and typically based on seniority, but even more so on technical expertise. These two criteria are very often related – those with seniority tend to have more technical expertise. However, technical expertise is valued above all else. The women in our interview cohort often reported identifying senior members, and especially senior members with expertise, as “models.” And while senior members may be identified as models, these women experienced little in the way of “top-down” mentorship. Something many of them, once established in the teams, sought to change. Also, they, and this is true of all members, were expected to commit themselves to the work and to the team. If this commitment required sacrifice, e.g., little sleep, no social life, and/or ignoring other academic responsibilities, so be it.

Apparent from the required commitment, project teams are very demanding. There is an unwavering expectation that all members will do whatever work needs to be done, to do so well, and on time. Self-directed learning or collaborative learning among team members is typical. The culture of the teams is very results- and goal-oriented. Members who cannot deliver those results or fail to meet goals sometimes leave the

team. When members do leave, continuing team members are understanding, yet rarely are there accommodations made to keep team members involved. Within the teams and between the sub-teams, there is a clear acknowledgement of their interdependence, and an almost palpable fear of “letting others down.” That interdependence contributed to the commitment that the women we interviewed felt toward the project team. A dedication to realizing results, to developing the necessary skills and expertise, to supporting the efforts of the other team members were recurring topics among the women we interviewed.

Unfortunately, project teams appear just as gendered, racist, and classist as the institutions in which they are housed. All of the women interviewees have reported direct and/or indirect experiences of gender bias. Instances of direct gender biases tend to be face-threatening challenges of their expertise or of their authority – of their becoming engineers – as team or sub-team leaders. The value placed on expertise and seniority, both clearly related to authority, in project teams suggests that these challenges are formidable. Instances of indirect gender bias tend to dismiss or at least neutralize gender, e.g., “I don’t think of you as a girl.” Also it is not unusual for these women to have to respond to feminine stereotypes: be cooperative rather than competitive, be assertive rather than aggressive.

We are not far along enough in our research to suggest with confidence how perceptions of gender may be complicated by race and class. Because we are focused on women who thrive in project teams, we are also unclear if women who left project teams, did so because of gender, race or class bias (although it is not unreasonable to assume that some women did leave because of those biases). However, it is the case that the women project team members that we interviewed strongly resisted, even openly defied instances of gender bias. They were unwilling to allow experiences of gender bias to compromise their membership and leadership within project teams. Of course, that resistance or defiance also came with consequences, often those women were “masculinized.”

Women project team members seemed most likely to experience gender bias when they assumed leadership roles on the teams. The leadership models these women identified for themselves often were not the ones currently present in team leadership. Consequently, they reported wanting to change the ways that leadership was enacted. They reported learning from problematic leadership that they and other team members had experienced. The changes that they wanted to make, and had some success making, when they assumed leadership positions were to facilitate new member growth and development, to encourage mentorship by creating more feedback opportunities for team and sub-team members, to develop training protocols, to delegate more responsibility and accountability among members, to foster reflective and supportive responses to mistakes and failures, and to emphasize communality. We believe that these women were aware of assuming what might fairly be characterized as a feminine style of leadership. Indeed, some mentioned having to learn how to make demands while also being supportive. They seemed to want their style of leadership

to provide a much needed balance to the hierarchical, results-oriented, demand and masculinist culture already in place in project teams.

C. Joy of doing engineering

The last major finding speaks to the single most important experience these women had while participating in project teams, the “joy of doing engineering,” as we describe it. According to Goldberg and Sommerville [27], joy is the first pillar of engineering educational transformation. They note that that joy is a result of overcoming complexity, seeing theory applied to real-life, and learning together. Through our distinctive focus and method, our early results suggest that these women are thriving because they experience joy in developing and applying engineering expertise, in knowing what and how to respond to real, tangible, and challenging problems. They reported finding knowing “what and how,” exciting, self-rewarding and self-defining.

We believe that this joy emerges in three phases. The first phase begins when they are introduced to relevant knowledge as novice team members. They begin to transform that relevant knowledge into usable knowledge, or knowledge that they can apply to a solution. The second phase begins when they start to see problems from more than a single perspective. They learn to use and appreciate established knowledge systems in engineering. It is during this second phase primarily that they begin to understand themselves not only as engineers but as certain kinds of engineers. It is during this second phase that they begin to recognize and affirm specific disciplinary interests. Finally in the third phase they begin to self-monitor their application, to change strategies when necessary, to make “educated guesses.” It is in this third phase that they begin to internalize discipline-specific norms and thereby routinize the use of discipline-specific tools. It is in this phase that they can facilitate the learning and doing of others. The above also seem to be important personal and contextual enablers. Their story culminates with them claiming their identity as engineers. They are no longer someone who models others, but rather someone who is modeled by others. We believe these women’s stories suggest an important pathway toward a genuine and more inclusive engineering educational transformation. That pathway, regardless of the many obstacles and difficulties, is to facilitate the joy of doing engineering.

IV. CONCLUSIONS

Our distinctive focus and methodology allows us to identify the situated instances of all the terms highlighted in positive psychology and human thriving: development and performance, motivation, challenge and resilience, trust and support. It allows us to locate these abstractions in the particulars of these women engineers’ experience. It allows us to see and understand these women as they see and understand themselves. However, it also allows us to get to know, at least a little, some very amazing women. And it suggests that if we are truly interested in change, then the pathway forward is to make doing engineering and being an engineer more joyful.

REFERENCES

- [1] K. Beddoes and M. Borrego, "Feminist theory in three engineering education journals: 1995–2008," *Journal of Engineering Education*, vol. 100, no. 2, pp. 281–303, 2011.
- [2] A. L. Pawley, C. Schimpf, and L. Nelson, "Gender in engineering education research: A content analysis of research in jee, 1998–2012," *Journal of Engineering Education*, vol. 105, no. 3, pp. 508–528, 2016.
- [3] D. Riley, A. E. Slaton, and A. L. Pawley, "Social justice and inclusion: Women and minorities in engineering," *Cambridge handbook of engineering education research*, pp. 335–356, 2014.
- [4] K. L. Tonso, *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*. Brill Sense, 2007.
- [5] A. L. Pawley, "Learning from small numbers" of underrepresented students' stories: Discussing a method to learn about institutional structure through narrative," in *Proceedings of the 2013 ASEE Annual Conference and Exposition, Atlanta, GA*, 2013.
- [6] K. Tonso, "Engineering identity," in *Cambridge handbook of engineering education research*. Cambridge University Press, 2014, pp. 267–282.
- [7] K. L. Tonso, "Teams that work: Campus culture, engineer identity, and social interactions," *Journal of engineering education*, vol. 95, no. 1, pp. 25–37, 2006.
- [8] V. L. Olesen, "Feminisms and models of qualitative research," in *Handbook of qualitative research*, 1994.
- [9] J. Sprague, *Feminist methodologies for critical researchers: Bridging Differences*. New York: Rowman & Littlefield, 2016.
- [10] R. E. Stake, "Qualitative case studies." 2005.
- [11] J. M. Case and G. Light, "Emerging research methodologies in engineering education research," *Journal of Engineering Education*, vol. 100, 2011.
- [12] A. L. George, A. Bennett, S. M. Lynn-Jones, S. E. Miller *et al.*, *Case studies and theory development in the social sciences*. mit Press, 2005.
- [13] D. J. Brown, R. Arnold, D. Fletcher, and M. Standage, "Human thriving," *European Psychologist*, 2017.
- [14] R. M. Lerner, E. M. Dowling, and P. M. Anderson, "Positive youth development: Thriving as the basis of personhood and civil society," in *Beyond the Self*. Routledge, 2019, pp. 172–180.
- [15] M. Sarkar and D. Fletcher, "Ordinary magic, extraordinary performance: Psychological resilience and thriving in high achievers." *Sport, Exercise, and Performance Psychology*, vol. 3, no. 1, p. 46, 2014.
- [16] P. L. Benson and P. C. Scales, "The definition and preliminary measurement of thriving in adolescence," *The Journal of Positive Psychology*, vol. 4, no. 1, pp. 85–104, 2009.
- [17] S. Beltman, C. Mansfield, and A. Price, "Thriving not just surviving: A review of research on teacher resilience," *Educational research review*, vol. 6, no. 3, pp. 185–207, 2011.
- [18] E. S. Epel, B. S. McEwen, and J. R. Ickovics, "Embodying psychological thriving: Physical thriving in response to stress," *Journal of Social issues*, vol. 54, no. 2, pp. 301–322, 1998.
- [19] V. E. O'Leary and J. R. Ickovics, "Resilience and thriving in response to challenge: an opportunity for a paradigm shift in women's health." *Women's health (Hillsdale, NJ)*, vol. 1, no. 2, pp. 121–142, 1995.
- [20] M. J. Bundick, D. S. Yeager, P. E. King, and W. Damon, "Thriving across the life span," *The handbook of life-span development*, 2010.
- [21] J. Liu and M. Bern-Klug, "Nursing home social services directors who report thriving at work," *Journal of gerontological social work*, vol. 56, no. 2, pp. 127–145, 2013.
- [22] J. Creswell, *30 essential skills for the qualitative researcher*. Sage Publications Ltd., 2016.
- [23] K. Crenshaw, N. Gotanda, G. Peller, and K. Thomas, *Critical Race Theory: The Key Writings That Formed the Movement*. New Press, 1995.
- [24] I. Goodson and P. Sikes, *Life history research in educational settings: learning from lives*. New York, NY: Open University Press, 2001.
- [25] H. Adriansen, "Timeline interviews: A tool for conducting life history research," *Qualitative Studies*, vol. 3, no. 1, pp. 40–55, Apr. 2012. [Online]. Available: <https://tidsskrift.dk/qual/article/view/6272>
- [26] A. O. Latz, *Photovoice Research in Education and Beyond : A Practical Guide from Theory to Exhibition*, T. . F. Group, Ed. Routledge, 2017.
- [27] D. Goldberg and M. Somerville, "A whole new engineer: The coming revolution in engineering education, threejoy associates," *Inc. Douglas, Michigan*, 2014.