Making Sense of Gender Differences in the Ways Engineering Students Experience Innovation: An Abductive Analysis

Dr. Nicholas D. Fila, Iowa State University

Nicholas D. Fila is a postdoctoral research associate in Electrical and Computer Engineering and Industrial Design at Iowa State University. He earned a B.S. in Electrical Engineering and a M.S. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign and a Ph.D. in Engineering Education from Purdue University. His current research interests include innovation, empathy, design thinking, and instructional design heuristics.

Dr. Rachel E. Friedensen, Iowa State University

Dr. Rachel Friedensen is currently a postdoctoral research associate at Iowa State University. She recently received her Ph.D. in education leadership and policy with a specialization in higher education from University of Massachusetts Amherst. She also holds a masters degree in history from Western Michigan University and a bachelors degree in history from Bryn Mawr College. Her research interests include: underrepresented populations in STEM; student engineering identity development; institutional diversity and equity policy; history and theory of higher education.

Dr. Mani Mina, Iowa State University

Mani Mina is with the department of Industrial Design and Electrical and Computer Engineering at Iowa State University. He has been working on better understanding of students' learning and aspects of technological and engineering philosophy and literacy. In particular how such literacy and competency are reflected in curricular and student activities. His interests also include Design and Engineering, the human side of engineering, new ways of teaching engineering in particular Electromagnetism and other classes that are mathematically driven. His education research and activities also include reframing and finding ways to connect Product Design and Engineering Education in synergetic ways.

Dr. Benjamin Ahn, Iowa State University

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Introduction

The different experiences and outcomes for male and female students in engineering have long been a focus of engineering education research. In the spaces of engineering design and innovation, researchers have explored differences in the ways male and female students approach conceptual design tasks[1], their unique experiences working on a variety of engineering design projects[2,3], differences in propensity for engineering creativity[4], and the innovative outcomes of student projects from gender homogenous and heterogeneous teams[5,6].

Collectively, these and other studies suggest that female and male engineering students may tend to approach and experience innovation in different, but not necessarily better or worse, ways. One of the authors used these studies, in part, to situate and design a recent phenomenographic study that investigated variation in the ways engineering students experienced innovation[7]. This study resulted in eight distinct ways that engineering students experienced innovation. Further, these ways of experiencing innovation (or categories) resided on a two-dimensional outcome space that demonstrated increasing comprehensiveness (i.e., sophistication, complexity) across dimensions describing innovation processes and innovation focus areas. As expected based on previous findings, individual male and female students often differed in their ways of experiencing innovation, i.e., categories were often comprised mostly of male participants or mostly of female participants. However, one unexpected finding was that female students were more likely to align with the most comprehensive ways of experiencing innovation, which had not yet been suggested by the literature.

This paper seeks to more thoroughly understand this finding through abductive analysis[8], a novel analytical framework that supports sense-making and theory development based on unexpected findings. Unlike deductive analysis, which focuses on generating and testing hypotheses based on extant theory, and inductive analysis, which focuses on meaning within the data and connects findings to theory post hoc, abductive analysis represents a dialectic “conversation” between data and theory. Abductive analysis follows an iterative cycle of hypothesis generation that could explain unexpected findings and then exploration of potential hypotheses within the data, which will often result in new unexpected findings and refinement of hypotheses. Abductive analysis is “complete” once a new theory is generated that can explain the unexpected finding(s) and is supported by the data.

Thus, in this paper, we attempt to address the following research question through abductive analysis:

> What theoretical formulation can help explain why female engineering students were more likely to experience innovation in more comprehensive ways than male engineering students?

The Unexpected Finding

A phenomenographic study by the first author identified eight distinct ways engineering students experienced innovation (categories)[7]. These categories were mapped to a two-dimensional outcome space that differentiated categories by the processes participants connected to innovation and the areas around which they focused their innovation activities (Figure 1).

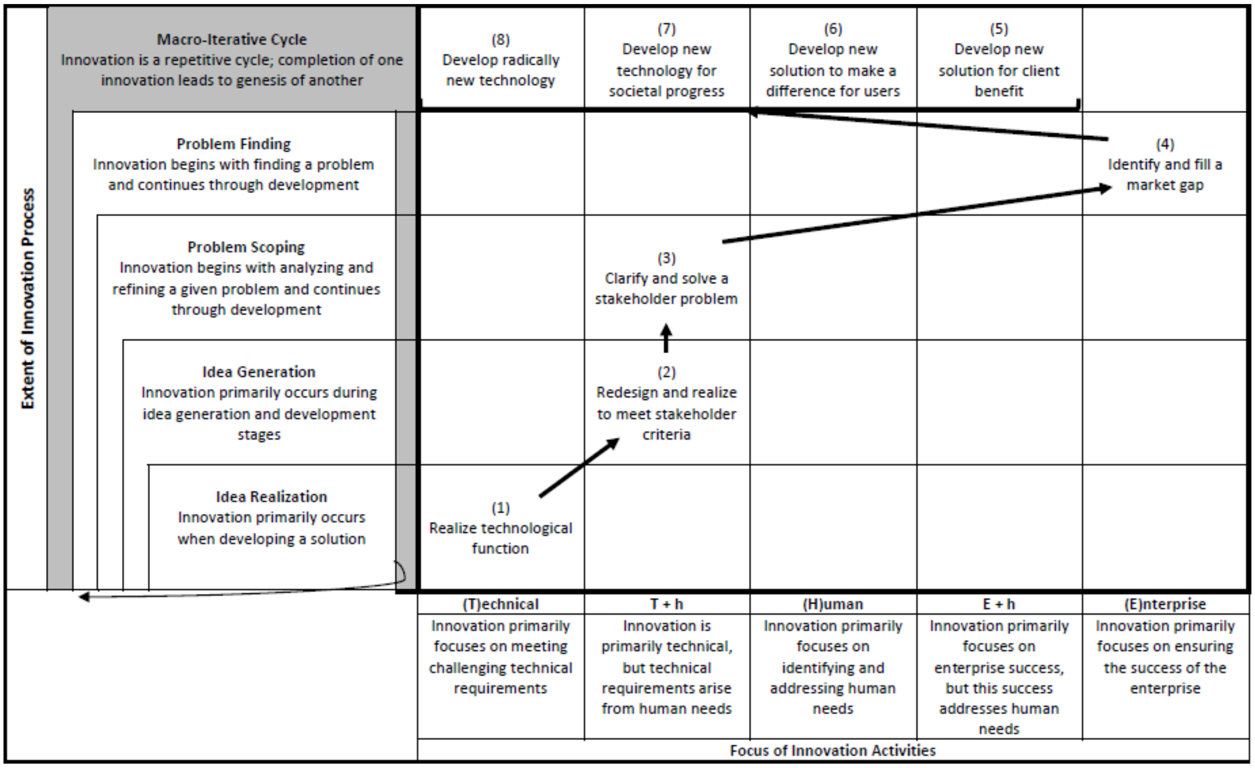

Figure 1. Outcome space demonstrating ways of experiencing innovation (from[7])

Collectively, categories 5–8 represented the "most comprehensive" categories because they incorporated all process elements (idea realization, idea generation, problem scoping, problem finding, and the macro-iterative cycle) and all focus areas (technical, human, and enterprise) into their ways of experiencing innovation. The primary difference was the degree to which they emphasized different focus areas. For example, Category 8 participants focused primarily on technical aspects of innovation, but incorporated human and enterprise aspects as well, while Category 5 participants focused primarily on enterprise aspects of innovation, slightly less on human aspects, and even less on technical aspects.

Collectively, categories 1–4 represented the "less comprehensive" categories because they had not yet incorporated all process and focus elements evident in the study. Still, participants aligned with Category 4 could be considered to experience innovation in more comprehensive ways than those aligned with Categories 1–3.

The current study originated with the finding that female participants were more likely than male participants to align with the four most comprehensive categories (Fisher's exact, $p = .03$). While the literature that informed the study suggested that male and female engineering students may have different approaches and experiences with engineering design, and correspondingly may experience innovation in different ways, there was no assumption (or obvious basis in the literature) to suggest that female or male students would demonstrate more comprehensive ways of experiencing innovation. Thus, we initiated this abductive analysis to further explore this unexpected finding.

It should be noted that this finding does not necessarily suggest that female engineering students are "better" innovators. It simply acknowledges that, in general, the female participants in the study held more complex and sophisticated understandings of innovation. Further, while this gender difference provided the original impetus for this study, the utilization of abductive analysis allows the flexibility to follow promising theoretical pathways that do not directly or solely relate to gender. This study acknowledges the possibility that personal and contextual factors that were more common, but not exclusive, among female participants may have supported the difference in comprehensiveness. Thus, while this study nominally addresses why female engineering students were more likely to experience innovation in more comprehensive ways, it may uncover broader themes in how different engineering students learn about innovation.

Method: Abductive Analysis

The methods of this study were adapted from Tavory and Timmermans'[8] discussion of abductive analysis and Dong, Garbuio, and Lovallo's[9] model of generative sensing within robust design review conversations. We followed an iterative process, as described by the four steps below:

1. ***Document unexpected finding*** - Abductive analysis begins with the acknowledgement of an unexpected finding. This can be something that does not fit the study's hypothesis, an outlier in the data, or something that does not resonate with your current understanding and theory. The outcome of this stage should be a description of the finding and why it is unexpected.
2. ***Generate hypotheses*** - Once the unexpected finding is recognized and documented, a team with diverse perspectives and expertise meets to discuss the finding and ideate potential explanations for why the unexpected finding might have been observed. This involves discussing potential theories (often from other fields or disciplines) that could resolve on the unexpected finding. This stage should be treated like ideation in design processes; variety and volume are desired.
3. ***Test a promising hypothesis with extant data or plan a follow-up study*** - Once one or more promising hypotheses (i.e., adaptation of current theory) have been identified, the team develops a plan to test these hypotheses. In some cases, this could require additional data collection, but it may also involve returning to the original data with a new theoretical lens.
4. ***Iterate*** – The process "ends" once a hypothesis resolves the unexpected finding, typically resulting in a modified or new theory. However, often, the new analyses will reveal more nuanced unexpected findings or areas of the new/adapted theory that require further explanation, and the cycle continues.

We have currently explored three iterations of this process:

- First, we discussed gender theories and different experiences for male and female students, especially in engineering. This discussion supported understanding of how female students in the original study oriented more toward human-centered approaches and male students, also in the original study, oriented toward technical approaches. Then question became: why were these focus areas more comprehensive?
- Second, discussion moved toward more engagement with specific categories and how students might align with those categories. We spoke not only of gender differences, but other factors that could influence alignment with different categories (e.g., nationality). This expansion led the first author to consider the general patterns observed in another ongoing study[10] as well as additional theories the team had been discussing with others in the design of an engineering course.
- For the third iteration, the first author proposed a model based on the data and the results of the second iteration. The author presented this model and the others helped refine it with comments, questions, and suggestions for data. Another member joined the team here to offer additional perspectives, and due to his familiarity with professional formation. The remainder of the paper discusses and tests the hypothesis that resulted from this iteration.

Current Hypothesis

The current theorization has foundations in Ibarra's[11] framework for professional identity formation during a mid-career change, which consists of three processes:

- Engagement with professional activities – This refers to the process of identifying and learning the skills and knowledge aligned with the profession and connecting to professional roles or aspects thereof. In this study, we understood engagement with professional activities to be the coursework, group projects, internships, co-op experiences, and extracurricular design projects, among other experiences, in which these students engaged in what they considered to be innovation.
- Developing social networks – This refers to building communities of others engaged in the professional and understanding one's place in that network of peers. We understood these students' social networks to be those individuals (e.g., students, engineers, instructors, etc.) with whom they interacted in the activities listed above.
- Sense-making – This refers to the reflective work in which one comes to terms with the realities and requirements of the profession and begins to resolve these aspects with their own interests. While sense-making as a process is generally similar across experiences, this study focuses on sense-making with respect to innovation and innovation experiences.

In this study, we adapt Ibarra's framework to the process of engineering students coming to experience innovation in increasingly comprehensive ways. Here, coming to experience innovation in a new way is recognized as a shift in professional identity as it signifies a change in the way one relates to the phenomenon, which results in both a change in processes (i.e., approaches) acknowledged and aspects (e.g., technical, human, and enterprise) emphasized[7]. Figure 2 demonstrates a linear structure in which professional activities and social networks provide the impetus for sense-making, which can result in new ways of experiencing innovation.

This results from individuals making sense of these professional experiences and encounters with a social network, and feeds back into new experiences with professional activities and social networks.

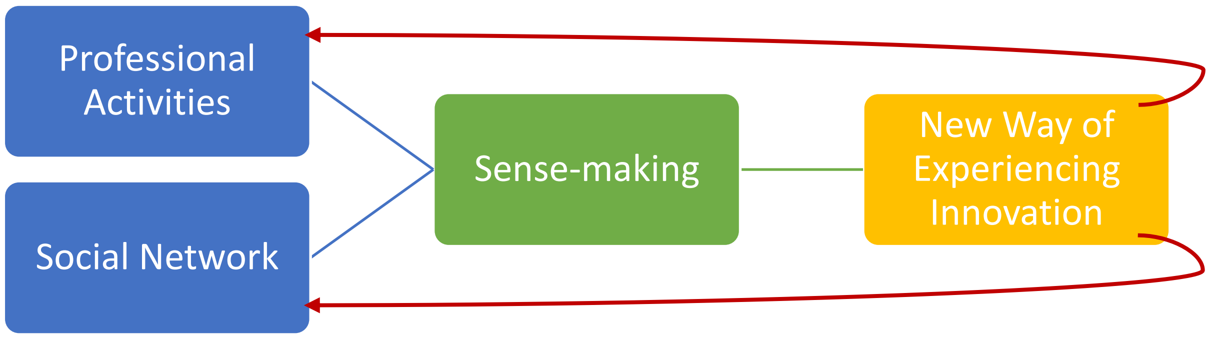

Figure 2. Proposed Model of Change in Way of Experiencing Innovation (adapted from Ibarra[11])

This model is further informed by a follow-up to the original study that identified three ways individuals moved to more comprehensive ways of experiencing innovation[12]:

1. ***Experiencing innovation in more complete and varied settings*** – Individuals who experienced more elements of innovation, through more authentic projects and more comprehensive roles, as well as participating in a greater variety of innovation projects across which they could compare aspects, were more likely to experience innovation in more comprehensive ways.
2. ***Connecting innovation projects to interests and expertise*** – Individuals who participated in projects aligned with their interests and expertise were more likely to contribute and deeply engage (procedurally and cognitively) with the project, and recognize unique and nuanced elements of those projects, resulting in more comprehensive ways of experiencing innovation.
3. ***Experiencing either acute failure or persistent tensions during innovation projects*** – Individuals who experienced (and reflected upon) substantive conflict between prior approaches, perspectives, and mindsets and those that would support greater innovative success in new contexts were more likely develop more comprehensive ways of experiencing innovation that incorporated the new approaches, perspectives, and mindsets they identified.

These themes add to the above model by describing potential pathways through which professional activities and social networks can translate to new ways of experiencing innovation. Theme 1 describes how participating in more complete professional activities and social networks might provide new elements upon which sense-making can be built. Those who engage with a greater variety of innovative projects with a greater variety of individuals might experience more elements of innovation upon which to reflect, potentially integrate into their way of experiencing innovation. Theme 2 demonstrates the role motivation and participation (e.g., through alignment with interests and expertise) can play, especially as processes that drive recognition of the unique features of new innovation projects described by theme 1. In other words, while participants may experience new elements innovation through their more complete and varied activities and social networks, they may not necessarily recognize or engage with these elements without the proper motivation or opportunity to participate. Finally, theme 3 demonstrates the important role reflection can play in translating these experienced elements into new ways of experiencing innovation, and the important role conflict can play in inspiring reflection. In the next section, we explore this abstracted model through data from the original study and attempt to answer two key questions: (1) how well does the model above describe the process of coming to experience innovation in a new way and (2) how, if at all, do male and female engineering students tend to experience these processes differently (i.e., how well does it explain the unexpected finding)?

Testing the Current Model

This section addresses the above questions through the exploration of critical incidents[13,14] representing a change in the way one experienced innovation that were identified in a concurrent study led by the first author[10]. For the purposes of this study, we defined a critical incident as any event, extracted from students' verbal responses, in which the engineering students described or demonstrated **a change, refinement, or crystallization** of their way of **understanding the act, process, idea, or nature of innovation**, or their approach toward innovation, because of a specific incident or set of incidents. More specifically, to be considered a critical incident, the verbalization must have contained[10] (p. 7):

1. Description or demonstration of one or more aspects of understanding or approaching innovation. Direct connections to innovation were preferred, but this connection could be inferred from a participant's way of experiencing innovation or contextual cues in the interview and/or excerpt.
2. Detailed description of an experience or series of experiences that are directly attributable to the aspect(s) of their way of understanding or approaching innovation.
3. A clear change, refinement, or crystallization in one's view of innovation, especially as it addressed aspects of that participant's way of experiencing innovation.

To identify critical incidents, the first author reviewed the transcripts of interviews with 16 engineering students, during which they discussed 1–3 projects during which they experienced innovation, 1–2 projects during which they did not experience innovation, and their conceptual understanding of innovation. These interviews were originally reported and described in the initial study[7]. The 16 participants were chosen based on the uniqueness of their way of experiencing innovation (two participants, one male and one female, chosen at random from each of the eight categories describing different ways of experiencing innovation). There were a total of 7 female and 9 male participants (the least comprehensive category was comprised of males only) and each are described in Table 1.

There were a total of 194 potential critical incidents. A second researcher reviewed these incidents and applied the three criteria above to assess agreement. The two then met to discuss the incidents and decide upon appropriate critical incidents. The collaborative assessment refined the sample to 122 critical incidents and resulted in 10 distinct types of critical incidents, which are used below to explore the suitability of the proposed model.

Table 1. Participants

Pseudonym	Category	Major	Year	Gender	Engineering Design Project Experience
Jerry	1	First-year	First-year	Male	Design competition club team; Personal projects
Matt	1	Mechanical	Senior	Male	Sophomore design, Service learning
Hannah	2	Chemical	Sophomore	Female	Service learning, Design competition club team
Snow	2	Mechanical	Senior	Male	Co-op
Maria	3	Industrial	Junior	Female	Internship, Class Projects, Student Organization
Tony	3	Industrial	Senior	Male	Service learning, Senior design
Esteban	4	First-year	First-year	Male	Self-initiated start-ups; First-year engineering design projects
Jessica	4	Biological	Sophomore	Female	Course projects, Club projects, Personal projects
Ella	5	Industrial	Senior	Female	Internships, Service learning, Personal projects, Service learning club
Verdasco	5	Mechanical	Junior	Male	Service learning, First-year course project
Elon	6	Mechanical	Senior	Male	Co-op, Internships, Sophomore design, Design competition club team, Personal projects
Sarah	6	Chemical	Senior	Female	Service learning, Internships
Dylan	7	Biomedical	Senior	Male	Senior design, Internships
Taylor	7	Computer	Senior	Female	Junior-level course projects, First-year engineering course, Internship, Student organizations, Personal robotics project
Chris	8	Nuclear	Graduate	Male	Long-term personal start-up
John	8	Acoustical	Senior	Female	First-year engineering course, Service learning, Internship

Complexity and Variety of Professional Activities and Social Networks

To identify any differences in the complexity and variety of professional activities and social networks, we explored student responses to a question asking them to list the contexts in which they "worked on engineering design projects" which had the potential for innovation. We organized these results by six project types (service learning, in-course projects, internships/co-ops, club projects, senior design, and personal projects/startups), which signified distinct opportunities for engagement in professional activities and building social networks as described in incidents referring to those project types (Table 2).

Female students were more likely to have experienced each of these types of projects (see Figure 1), but the only significant difference was in internships/co-ops (Fisher's exact, $p = .03$). Since each participant experienced multiple types of projects, we saw little substantive difference in the complexity and variety of professional activities and social networks experienced by male and female students in the context of innovation.

Table 2. Innovation project types

Project Type	Description	Professional Activities	Social Networks
Club project	An engineering design project often competing with other teams to meet specific, measurable criteria.	• Working with authentic hardware • Building tangible systems or products • Formal presentations or demonstrations	• Teams with fellow students • Competition with other teams • Interaction with club mentors
Course project	An engineering design project completed within a technical engineering course, typically focused on a specific topic or hardware area.	• Working with authentic hardware • Building tangible systems or products • Formal presentations or demonstrations	• Teams with fellow students (often in same major) • Interaction with faculty and teaching assistants
Internship/co-op	One or more engineering design projects in a real company	• Building tangible systems and products for real markets • Participating in multiple aspects of professional engineering workplaces • Research and development	• Teams with professional engineers • Engineering mentors and supervisors
Personal project/startup	An engineering design project intended to be the basis of a new business or venture	• Building tangible systems and products for real markets • Scientific and/or market research • Securing funding and resource • Formal presentations and demonstrations to clients and/or funding sources	• Teams with fellow students • Interaction with financial resources • Interaction with faculty mentors
Senior design	A yearlong engineering design project intended to act as a capstone to an undergraduate education	• Working with authentic hardware • Building tangible systems or products • Formal presentations or demonstrations	• Teams with fellow students (often in same major) • Interaction with faculty and teaching assistants • Interaction with clients and professional engineers
Service learning	Co-curricular engineering design projects for authentic community stakeholders	• Working with authentic hardware • Building tangible systems or products for use in real communities • Interaction with users and clients • Formal presentations or demonstrations	• Teams with fellow students (often from different majors) • Interaction with faculty supervisors • Interaction with clients and professional engineers (during reviews)

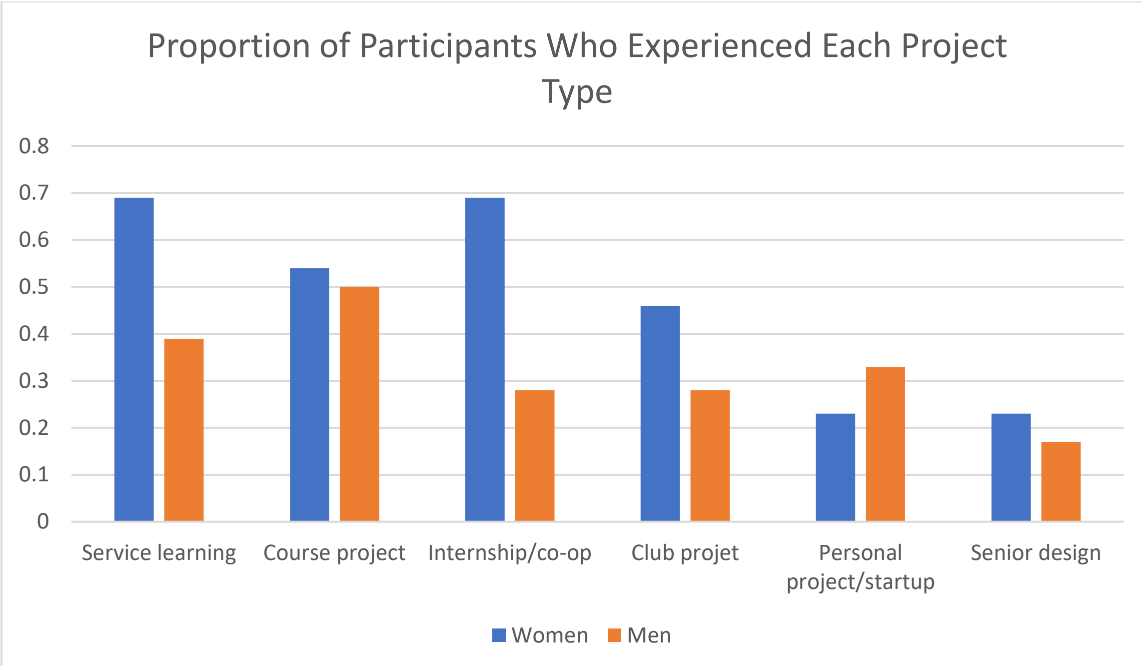

Figure 3. Comparison of types of project experience by gender

Engagement with Professional Activities

The previous section demonstrated that, for the most part, male and female students participated in similarly comprehensive and various professional activities. In this section, we explore potential differences in how male and female students deeply engaged with professional activities related to innovation within these projects and passed those experiences to sense-making.

Two types of critical incident are important for this element of the model: *I'll do it my way* and *trying new approaches*. Both incident types demonstrated the approaches participants used during their innovation projects, where those approaches originated, and how participants came to align those approaches with successful innovation. With *I'll do it my way*, participants relied on prior engineering approaches they had developed, used, and enjoyed in the past. In many cases, these approaches were used in lieu of alternative approaches that were suggested by others or more aligned with their new project environments. In other words, participants staunchly opposed or ignored alternative approaches and considerations. Conversely, with *trying new approaches*, participants attempted new approaches, either due to requirements, suggestions, or their own inspiration, and observed how those new approaches and considerations connected to innovation. Table 3 compares the number of incidents in of these categories that were described by male and female students.

Table 3. Incidents related to engagement with professional activities

Type of incident	**Male students**	**Female students**
I'll do it my way	13	4
Trying new approaches	9	14

The above results suggest that male students tended to favor their own, rather than alternative approaches, in novel innovation settings, compared to female students, who tended to favor trying new approaches that were potentially more responsive to novel innovation settings. Thus, in the face of new professional activities in innovation environments, female participants were more likely to engage with and learn from these elements, while male participants were more likely to ignore these elements in favor of current approaches.

The cases of Matt and Hannah demonstrate this difference. Matt's sophomore design project had a requirement to identify users and consider their needs. He ignored this aspect of the project, and instead followed a tech/build-oriented "barnyard engineering" approach that he favored and aligned with innovation. Thus, while Matt encountered the user element of innovation, he did not engage with it, and thus did not attempt to reflect upon it. Conversely, Hannah engaged more deeply with the users in her service learning project, in part due to an assignment to document user contexts and needs. Hannah preferred a similar tech/build-oriented approach to Matt's, but also engaged with this user documentation aspect when asked. This is not to say that male students ignore and female students completely engage with all novel aspects within new innovation contexts, only that different tendencies are observable and that willingness to engage with novel innovation approaches may support development of more comprehensive ways of experiencing innovation.

Engagement with Social Networks

The first section of this results exploration demonstrated that, for the most part, male and female students participated in, or had the opportunity to participate in, similar social networks. In this section, we explore potential differences in how male and female students deeply engaged with social networks within innovation projects and passed those experiences to sense-making.

Three types of critical incident are relevant to this element of the model: *observing colleagues*, *reflecting on historical examples*, and *reflecting on external evaluation*. In *observing colleagues* incidents, participants interacted with teammates (peers, engineers, clients) and reflected on the aspects of their knowledge, skills, and actions that contributed to or detracted from innovation. Often, they compared others' knowledge, skills, and actions to their own, thus further understanding how they took and did not take approaches conducive to innovation. In *reflecting on historical examples*, participants substituted teammates from the above example with historical and current innovation figures such as Steve Jobs, Thomas Edison, and Elon Musk. In *reflecting on external evaluation*, participants interacted with supervisors (e.g., instructors or professional engineers), who evaluated the participant's work as innovative. Table 4 compares the frequency with which female and male students communicated each incident.

Table 4. Incidents related to engagement with social networks

Type of incident	**Female students**	**Male students**
Observing colleagues	6	5
Historical examples	3	8
External evaluation	0	2

Overall, male participants demonstrated more incidents connected to social networks (15/9). Their incidents favored comparison to or evaluation from professionals in the innovation space through historical comparisons and external evaluations. By comparison, female participants demonstrated a slightly greater proportion of incidents learning from their peers (6/5). These results suggest a potential difference in the ways male and female engineering students factor social networks into sense-making, i.e., a focus on collaborators for female students and role models for male students. However, social networks may play additional roles in learning from other incidents that may have been too nuanced for this analysis.

Sense-making

The previous sections suggest that while male and female students may tend to experience similar innovation projects, female students may be more likely to deeply engage with new professional activities and may tend more towards learning from social networks of collaborators rather than role models. Collectively, these results suggest that female students may factor a greater volume and variety of innovation elements into their sense-making compared to male students. This section focuses on the characteristics of their sense-making and how they may differ.

Sense-making needed to be present to consider an incident critical. Thus, to some extent, comparison of the total number of critical incidents provides some evidence of differences. On average, female participants described 8.14 critical incidents (57 incidents over 7 participants) and male participants describe 7.22 critical incidents (65 incidents over 9 participants). However, a more telling result may come from comparison of the two categories of critical incident that came from strong conflict and resulted in deep sense-making among the participants.

The first type of incident that demonstrated deep sense-making was *immersion in novel innovation ecosystems*. In these incidents, participants were involved in new project settings that featured novel elements which caused cognitive dissonance for the participants. For example, participants often needed to resolve older mindsets focused on technological complexity with new business and/or user considerations. Only through substantial reflection did they resolve these internal conflicts and come to new appreciations of more complex conceptions of innovation.

The second type of incident that demonstrated deep sense-making was *acute failure*. In these incidents, participants experienced resounding failure of an implemented solution or advanced prototype. This failure inspired frustration and/or anger and caused the participant to reflect upon how their mindsets and/or approaches might have led to that failure. The sense-making they undertook caused new perspectives on innovation, that participants applied successfully to new projects or iterations on the failed projects. In the four cases of this type of incident, it could be observed that the *immersion in novel innovations ecosystems* pattern might have applied if participants had recognized the conflict between approaches earlier.

Table 5 compares the frequencies with which male and female participants described each type of incident. The results show that female students demonstrated more incidents of deep sense-making and these were all aligned with resolving cognitive dissonance. Comparatively, male students demonstrated fewer instances of deep sense-making and were aligned more with learning from acute failure (all three instances of *immersion in novel innovation ecosystem* among male students came from the same participant). Collectively, these results show that male students tended to follow a sense-making trajectory of gradual changes based on success and sharp changes based on failures, while female students seemed to more frequently and deeply reflect on their approaches and perspectives in light of their new experiences and encounters in the innovation world.

Table 5. Incidents related to sense-making

Type of incident	Male students	Female students
Immersion in novel innovation ecosystem	3	11
Acute failure	4	0

Next Steps

Analysis of the extant data demonstrates that the current model presents a promising theory that could help understand differences in the way male and female engineering students develop their ways of experiencing innovation. To summarize: female students demonstrated more engagement with new professional activities, favored learning from collaborator social networks, and engaged more readily in deep sense-making without prior to any acute failure. Conversely, male students demonstrated more engagement with professional activities already aligned with their preferences, favored learning from established role models, and engaged less readily in deep sense-making unless they experienced acute failure. More importantly, it demonstrates that Ibarra's[11] professional identity development framework can be adapted to the context of innovation students developing more comprehensive ways of experiencing innovation.

While this paper focused on male/female differences, the results more broadly serve to identify two potential pathways. The first pathway involved participants developing more comprehensive ways of experiencing innovation through engaging with novel professional activities and approaches, favoring learning from peers, and sense-making based on cognitive dissonance between previous approaches to innovation and those more applicable to new contexts. The second pathways involved participants developing more comprehensive ways of experiencing innovation through applying their own preferred methods, favoring learning from authoritative figures, and making sense of acute failures. Although the first pathway was more common to female participants and the second pathways was more common to male participants, that does not suggest that they are uniquely female or male ways of developing more comprehensive ways of experiencing innovation. For example, Verdasco, a male student in Category 5 reported several instances of *trying new approaches*, *observing others*, *immersion in a novel innovation ecosystem* and no instances of *I'll do it my way*, *reflecting on historical examples*, *reflecting on external evaluation*, or *acute failure*, and thus was more aligned with the first pathway. The results simply demonstrate that the first pathway may better support development toward more comprehensive ways of experiencing innovation and that female students may be more likely to align with the first pathway.

While these results show promise of the model, there are limitations. First, the sample size was too small to allow appropriate statistical comparison, while the focus of the original data did not allow the fine-grained qualitative analysis that could explore the nuances of the engagement with professional activities, social networks, and sense-making. Second, there may have been additional critical incidents that participants did not share due to the focus of the initial interviews. Further, it should be noted that the current findings did not show bifurcated approaches between male and female students; nor were they expected to. We simply explored frequency differences to describe tendencies.

Abductive analysis is an ongoing and iterative process. By presenting a potential model to describe different approaches to developing more comprehensive ways of experiencing innovation, this paper represents a substantive step in that process. But future iterations are need to elaborate upon and confirm this model, as well as to explore additional interesting or unexpected findings that have resulted from the first three iterations. In the remaining paragraphs, each author further reflects on these findings and discusses further avenues for analysis, theorization, and research. To demonstrate the value of diversity in the research team, we each present our individual, unedited thoughts, followed by concluding remarks by the first author.

Second Author

For me, these findings resonate strongly with my understanding of a) gender and feminist theory and b) the experiences of under-represented minorities in STEM fields. First, while avoiding gender essentialism, the data presented in this study reflect theories that emphasize the ways that women are socialized in different ways than men. Women are often socialized to look outward, beyond themselves, in order to fulfill expectations that they be both social and nurturing. This socialization can be seen in various arenas—the ways that women are often directed towards the "helping" professions, such as teaching and nursing, for example—but can be seen generally in this data in the women's orientation to the social. They both focus more on clients and users as well as teams. Rather than focusing on themselves and their work, these students focused on the social aspects, pushing back against "hero" stereotype of scientists and engineers. It is possible, considering the dearth of famous female engineers on the level of Steve Jobs and Elon Musk, that these female students simply do not see themselves reflected in the popular stereotype of an innovative engineers and, consequently, look to diverse sources of information and models in order to forge a path forward.

Additionally, research shows us the ways that women and other underrepresented minorities in the sciences must both focus on the social aspects of their work—in order to navigate the social minefields of academic departments and to find meaning in their work—and out-perform their peers. I see this particularly strongly in women's engagement in persistent tensions in innovation work, but also the social aspects. They must be attuned to both clients and teams in order to avoid missteps and thus prove themselves. They may not be able to support acute failures like male peers can, because they simply cannot afford to.
Moving forward, the results of this abductive analysis could be used to delve more deeply into the experiences of innovative female engineering students. Future research should use the model proposed above to understand these experiences. Additionally, this model could be used to intentionally design engineering engagement activities for female students at the secondary and postsecondary levels. It could also be embedded in studies about climate in engineering majors,

departments, or colleges in order to explore the intersections of gender, innovation, and climate. Finally, future studies could use these results as a springboard for exploring other demographic differences, including race, socioeconomic class, or citizenship status.

Third Author

The data is indicating possibly many ideas that we as engineering educators have been aware of in various forms. However, this makes us view it from various angles and perspectives. This is one of the strong points of this study. It seems to me that that male and female engineering students tended to encounter and engage with different professional activities and social networks, that lead them to feed different aspects of these encounters into sense-making. It seems that when facing the problems/challenges they internalize, sense-make, and place it within their cognitive needs. This is the part of their internalization to develop and experience self-actualization and transcendence (as the growth of thought/self is modeled in systems such as Maslow) that in many cases can and will be different. Perhaps the connections that they make, and the nature of their interactions, actualizations, and internalizations of the experience are different between the genders.

I would hope that readers and other patrons would share their takes from this data and discussions and share with us. As always, the process of data analysis, is an iterative process. It reminds me of the old horizontal problems where there are many possibilities and ways to view the data and the finding. In such studies we make connections, draw conclusions and develop perspectives/meanings based on our understanding of what students meant by their words. From and educator perspectives, it seems that we need to be careful not to inevitably suppress students' curiosity and damage their experience. There are many ways that students find their paths to innovation, learning, engaging, and sense making. We as educators need to walk the thin and delicate line between a true class inclusivity to enable all learners, beliefs, and thinkers, and providing enough meaningful engagements, challenges and thought-provoking activities for the students to engage and grow.

Finally, as an educator who has been interviewing and discussing similar issues with students of all walks, I believe one of the most interesting parts of this study is what happened to the students after their interviews. When they commit to their opinions and their stories, they also may change. I wish we could look forward and see how they changed based on the incidents of the interviews. We are trying to interpolate their ideas and connections to the past activities through their verbalization and connected stories. I keep wondering how did the interviews change them? That would be a great study that also needs to be done.

Fourth Author

Although there is a limitation with the current study (e.g., low number of participants), the study does highlight differences in the ways male and female engineering students engage in professional activities, social network, and sense-making, which could lead to differences in potentially how male and female students experience innovation. This finding leads to an important question on what the role of engineering educators is when educating students to be innovative and providing learning opportunities. It is important for engineering educators to first recognize gender differences exist in how engineering students engage in professional activities, social network, and sense-making. Second, it is important to highlight these differences with engineering students, so that students can self-reflect on their own practices, and possibly try different practices and seeing their effect. Third, engineering educators should develop learning modules or activities that encourage female and male engineering students to engage in professional activities, social network, and sense-making that encourages students to take different practices to their default practices. For example, with respect to engagement in professional activities, engineering educators may encourage male students to "try new approaches," instead of continuing to do "it on their own ways." Or, with respect to sense-making, encourage female engineering students to make acute failures. Different gendered engineering students should be open to new ways to engage in the three activities to open their perspectives and determine on their own how those new practices lead to different innovation experiences. Engineering educators should explore ways to create supporting environment that allows engineering students to take difference practices to experience innovation.

First Author (Concluding Remarks)

The purpose for this paper was twofold. The primary goal was to investigate an unexpected finding that demonstrated a greater proportion of female engineering students at the most comprehensive ways of experiencing innovation. This paper has demonstrated progress towards this goal by presenting a potential model that not only may explain the unexpected finding but uses that finding as a springboard to a deeper understanding of how engineering students (regardless of gender) may develop more comprehensive ways of experiencing innovation. A secondary, but still important, goal was to explore a novel research approach (abductive analysis). I would like to close this draft with a consideration of this research approach and what it meant for this study.

I find myself looking at the results and my co-authors' reflections and being revitalized by the possibilities a simple shift from inductive analysis to abductive analysis has entailed. No, we are not concluding this paper with a concrete set of recommendations. Yes, the results represent a promising model, but one that has limitations and requires further study. And yet, beyond these reported findings, there are a surplus of new directions to move in, new questions to answer, and new theories with which to connect. In the second author's response, how can gender and feminist theory help explain the differences in engagement with profession activities, social networks, and sense-making we tentatively identified? How might the lack of female innovation role models have affected how women see themselves as innovators? In the third author's response, what role does the research interview play in student sense-making? How might we take a tool that has been used by qualitative researchers for decades and employ it to support innovation education? In the fourth author's response, what would it look like if we promoted incidents more common among male engineering students for female students and vice versa? The possibilities keep coming with each new discussion. Hopefully, this paper helps inspire reflection among readers and create inspiration to explore the exciting new pathways we've identified, and more. We encourage interested readers to contact us with any feedback or new ideas based on the work presented in this paperas we continue our journey with abductive analysis!

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