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Facilitating women's success in software engineering through the exploration of non-traditional educational environments

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1. Introduction

Software engineering and STEM fields face persistent challenges with diversity, equity, and inclusion. For example, while women make up 56% of students enrolled in undergraduate degrees, women account for only 22% of the students in engineering programs. This number drops even further in the workforce, where women comprise only 15.9% of the engineering industry [1]. Consequently, the industry of equity-focused coding education grew rapidly from the 2010s until 2024, leading to the creation of coding bootcamps, workshops, and community-based coding education specifically designed to increase the participation of women in tech [2], [3]. Recent funding shortages in 2024 and anti-DEI legislation in 2025 have led to the closure of many such groups, including Women Who Code and Girls in Tech. Despite these challenges and while the impacts of these sites of coding education are many and varied, equity-oriented coding education programs have much to offer software engineering educators invested in exploring inclusive pedagogy [4], [5], [6].

As faculty and students working within technical communication and engineering, our research team seeks ways to foster inclusive learning environments and help women thrive in software engineering. To that end, this paper offers pedagogical insights derived from an IRB-approved, multi-year qualitative study of sites of coding education created to increase representation, access, and equity in the tech industry. While this research centers the experiences of women in software engineering education, we take an intersectional approach attentive to the ways in which students' lived experiences are influenced to varying degrees by the many facets of their positionality, including race or ethnicity, first generation status, socioeconomic background, and more [7].

Our paper shares practices from software developers working to increase equity in tech and analyzes how these coding organizations use inclusive practices to cultivate participants' computational thinking and programming skills in the context of a constantly changing coding landscape. The study uses interviews, participant observation, and grounded theory analysis to better understand the pedagogical practices of these coding organizations. Ultimately, this research seeks to offer a framework to critically evaluate pedagogical practices for software engineering education as well as specific strategies for cultivating a more inclusive learning environment and improving the learning experiences of underrepresented students in engineering.

2. Study Exigence and Research Questions

Our study exigence arises from both our academic commitments and personal experiences. Our research team consists of one technical communication faculty member who co-teaches with engineering faculty in advanced capstone design courses, and three undergraduate researchers

majoring in software engineering and aerospace engineering. Our faculty researcher witnesses challenging classroom dynamics and conducts studies on inclusive pedagogical strategies with her engineering colleagues. Our student researchers, all women, have firsthand experience of the ways in which their gender identity can sometimes impact their educational experiences in the classroom and their professional experiences as interns at major aerospace and software engineering firms. We believe these combined personal and academic experiences position our team effectively to conduct further research on equity-centered software engineering pedagogy.

Existing scholarship on educational equity and software engineering suggests that women in software engineering face numerous barriers, including [8]:

- Implicit biases and stereotype threat: Implicit biases often lead to the undervaluation of women's abilities, while stereotype threats can hinder performance and confidence in technical fields [9].
- Lack of role models: The underrepresentation of women in academic and industry settings limits the availability of mentors and role models, reducing the visibility of successful pathways in software engineering [10].
- Gendered team dynamics: Research by Adams et al. [11] demonstrates women in engineering programs can experience marginalization in team projects, where they may be relegated to non-technical roles or have their ideas dismissed.

The cumulative effect of these challenges can create a hostile environment that discourages women from persisting in software engineering programs and careers.

Addressing these critical exigences, our study seeks to answer the following questions:

RQ1. How is coding literacy understood, taught, and practiced across educational sites designed to increase representation, access, and equity in technology?

RQ2. What are the implications of these approaches for software engineering education?

3. Literature Review

To frame our research on software engineering education, we draw on scholarly literature concerned with issues of representation, access, and equity in software engineering classrooms and industry.

Challenges with representation in university software engineering education begin in K-12 educational contexts. Students who identify as underrepresented based on their race and/or gender are less likely to have access to coding learning opportunities and technologies [12]. Similarly, Lee found that women are less likely to take CS classes in high school, a factor correlated with lower participation in STEM majors at the university level [13]. As a result, Lee argues for increased integration of CS content across K-12 curriculum and a more rigorous CS curriculum at the secondary level [13]. While Lee's research offers valuable insights into women's experiences in CS education, complex problems of gender equity demand more expansive solutions that account for disciplinary culture, students' networks of support, and

pedagogical approaches. Additionally, barriers like high costs, limited geographic availability, and insufficient access to reliable internet or technology affect underrepresented students, worsening inequities in access to coding education [14]. While university programs are often less explicitly oriented to issues of diversity and equity, researchers in CS education have considered how to reduce gendered performance gaps [15], offered strategies to combat colorblind coding pedagogies [16], and theorized equity-focused approaches to engineering education [17].

Drawing on their decades of work toward equity in the tech industry, Whitney and Taylor [18] offer suggestions for increasing women and underrepresented minorities in computing. They describe one university initiative called BRAID (Building, Recruiting, and Inclusion for Diversity) that uses a four-part approach to transform CS education. First, they urge universities to reimagine introductory programming courses to "make them more appealing and less intimidating" [18, p.29]. Prevailing models of university CS education privilege students who learn coding prior to entering the university, a phenomenon that contributes to increased drop-out rates for students without previous coding experience [19]. Second, universities can form partnerships with high school programs to "build a diverse pipeline of students" [18, p.30] and third, universities can do more to foster student confidence and community through peer-mentoring programs and technology conferences for underrepresented students (i.e. the Grace Hopper Celebration or Anita Borg Institute). Finally, Whitney and Taylor suggest developing joint majors (for example, biology and computer science) to attract a more diverse range of students [18].

3.1 Inclusive Pedagogy

Inclusive pedagogy fosters student engagement and success by addressing individual differences and systemic inequities [20]. Frameworks like social constructivism and equity pedagogy emphasize collaborative learning and strategies to combat structural injustices, ensuring all students have equal opportunities. Inclusive pedagogical strategies include developing a curriculum that integrates effective instructional and assessment methods, such as group projects, peer mentoring, flipped classrooms, project-based evaluations, real-life applications, and collaborative assessments. Providing constructive feedback and opportunities for improvement can foster an environment where all students can succeed. Inclusive practices have been shown to improve academic performance, retention, and sense of belonging, particularly in STEM [21]. Research suggests that even small interventions for fostering equitable communication and addressing implicit biases can improve women's experiences in team settings, creating more inclusive learning environments and improve students' ability to thrive [11], [22].

3.2 Exploring Non-Traditional Educational Environments

Activist software engineers created bootcamps and workshops explicitly designed to increase representation and access to coding education. Many of these workshops, meetups, and bootcamps are specifically designed for women, people of color, and LGBTQIA+ individuals. For example, one notable bootcamp working for equity and representation in tech is Ada

Developers Academy. Ada Developers Academy is a “non-profit, tuition-free coding school for women and gender-diverse adults” with a particular focus on serving “low-income people, underrepresented minorities, and members of the LGBTQIA+ community” [23]. The Ada program includes six months of full-time instruction followed by a five-month paid internship coupled with continuing education in computer science fundamentals. These organizations illustrate some of the ways in which bootcamps can be reimagined to increase access to coding education, address technical skill gaps, and foster a sense of community and support through mentorship and alumni networks [23].

Massive open online courses such as Coursera offer programs like "Advancing Women in Tech: Leadership Principles for Software Engineers," which provide tailored content and support for women entering technology fields. These platforms help bridge the gender gap by allowing learners to access education while balancing other responsibilities [24]. Community-led initiatives like Girls Who Code and Black Girls Code empower women in software engineering across various age ranges. Girls Who Code focuses on participants aged 18 to 25, offering workshops, mentorship opportunities, and networking events to support women in early career stages. Black Girls Code, targeting ages 7 to 25, allows younger learners to develop foundational coding skills while fostering a love for technology. These programs emphasize peer support and mentorship, helping women and girls build their technical expertise and confidence [25], [26].

These non-traditional environments are designed to help participants feel a sense of belonging in the industry. In these settings, educators have created equitable opportunities for women to enter and succeed in software engineering by integrating inclusive pedagogical approaches into their pedagogy.

4. Study Design

Ultimately, our study explores strategies that foster women’s success in software engineering through inclusive pedagogical approaches and non-traditional educational environments. By considering alternative sites of coding education in conjunction with university software engineering courses, we hope to better understand differences and provide the groundwork to implement equity-focused educational interventions.

4.1 Study Context

Our research team is located in a small, engineering-focused university located in the Southwest. Our first round of data collection occurred from 2020-2021. The study involves two distinct environments with their own unique context: university classrooms and coding education meetups and workshops. We decided to re-run the study to have a more robust data set starting in fall 2024. Unfortunately, in response to new anti-DEI legislation in spring 2025, all of our participants for our second round of data collection withdrew from our study. We are currently in a new round of participant recruitment. Our data in this paper reflects the findings from our initial round of data collection.

The traditional educational environment considered in this study includes several of the university's low-level undergraduate coding classes. They are made up primarily of computer-focused majors and consist of undergraduates of all ages and skill levels. The non-traditional educational environments follow two avenues: meetups and bootcamps. Coding meetups and workshops serve a wider range of individuals than university courses, involving people from all different walks of life, skill, and experience. Our primary non-traditional object of observation, meetups consist of small, intimate groups discussing their interests and projects involving software engineering in a casual setting.

Each of these environments provides a fundamentally different experience that participants seek out for different reasons, offering valuable insights for our research team. Traditional environments have the backing of the academic institution and can provide a more structured, typical environment. Meanwhile, non-traditional environments are open to those on a less traditional path, those wanting a more casual experience, and those desiring the acquisition of a specific skill that might otherwise be unattainable.

4.2 Study Participants and Recruitment

This qualitative study aims to document software engineering education practices designed specifically to increase the representation of women in technology. Table 1 lists the case studies and interview participants for university programs, bootcamps and workshops, and meetups.

Table 1: Case Study and Participant List

Site of Coding Education	Case Study	Interview Participants
University Programs	C1: Introduction to Application Development class C2: Introduction to Computer Languages class C3: Intermediate Object-oriented Application Development class	Claire (C1 faculty) George (C2 faculty) Samuel (C3 faculty) Ping (MA graduate in computer science)
Coding Bootcamps and Workshops	W1: Coding workshop for women of color W2: Coding workshop for marginalized programmers W3: Gender-inclusive coding workshop on university campus	Olivia (W1 organizer) Kassandra (W1 participant) Sophie (W2 organizer) Danny (W2 instructor) Ana (W3 organizer) Julia (W3 instructor)
Coding Meetups	M1: Gender-inclusive national coding meetup organization	Drew (M1 chapter organizer) Kelsey (M1 participant) Shannon (M1 chapter organizer)

	M2: Gender-inclusive international coding meetup organization	Katherine (M1 participant) Neha (M1 participant) Erin (M2 meetup chapter organizer) Dana (M2 meetup chapter organizer)

4.3 Data Collection: Interviews and Observations

The methods for this study included qualitative semi-structured interviews and participant observations, where participants in coding meetups, bootcamps, and formal courses were asked to provide accounts of their coding acquisition process, and how their participation influenced their perceptions of programming languages, as well as their sense of self in the community. We used a semi-structured approach, working with a standard set of questions and asking unscripted follow-up questions when needed. Some interview questions are included below:

1. Has this event/organization facilitated your coding education in any way? If so, how?
2. Does the content of this event transfer to your professional roles in any way? If so, how?
3. What made you decide to learn to code?
4. How would you describe the process of learning to code?
5. What technical skills do you need for your current role?
6. How do you acquire new skills if you need to?
7. What do you see as the relationship between your participation in this organization and your coding literacy?
8. What do you see as the relationship between coding and identity?
9. To what extent have you experienced challenges in your industry?
10. Has your participation in this event/organization influenced how you react to challenges in your occupation/industry?

Educators from these contexts were also interviewed about their definition of programming literacy, their pedagogical practices, and their aims for the meetups, workshops, and university courses. Finally, researchers conducted participant observations of the sites of coding education.

5. Data Analysis Methods:

In our first round of data collection in 2021, we used grounded theory [27], [28] to analyze the interview transcripts and observation notes. For the first coding cycle, we used in vivo coding to center participants' experiences in their own words. We organized the in vivo codes into related clusters and drafted analytic memos to reflect on our field notes and the in vivo codes in the interview transcripts. Examples of in vivo codes included, "inclusive, open, and culturally sensitive pedagogy," "community," and "transfer." For the second coding cycle, we used axial coding to categorize codes and draw out the relationships between them. Axial codes included "student outcomes," "literacy definitions," "exigencies," and "barriers to participation." For the final coding cycle, we used theoretical coding to better understand and identify participants' practices in each site of coding education.

6. Preliminary Findings:

Our initial round of data collection faced some limitations due to the COVID-19 pandemic. While we started this data collection by attending courses, meetups, and workshops in person,

we had to switch to remote data collection when the pandemic necessitated a shift to online instruction. Nevertheless, our initial data collection offered some valuable insights for software engineering educators.

In these preliminary findings, we discuss participant observations of three coding workshops and two coding meetups, coupled with interviews of thirteen coding bootcamp and meetup organizers, instructors, and participants. Coding meetups appeal to rhetorics of a "coding literacy crisis" to justify their work. These meetups offer strategies for individual and collective social action, in order to subvert exclusionary industry practices. The coding workshops included in this data set sought to practice approaches that increased access, centered representation, cultivated community, and facilitated active learning and an affective coding literacy.

Drawing on their professional and academic experience, coding workshop instructors strived to create welcoming learning environments for workshop participants, especially those who felt that coding was not "for" them. Their pedagogical practices reflect Vakil's call to move toward a "justice-centered view of equity" in coding education by thoughtfully considering the curriculum's content, the learning environment's design [12]. Vakil argues that prevailing DEI initiatives in tech often link equity to the needs of multinational companies, obscuring the "sociopolitical implications, relevance, and ultimately, liberatory possibilities of teaching and learning CS" [12, p. 27)] Unlike some K-12 and university coding education models, the coding workshops studied here are framed within more nuanced conversations about equity and ethics in technology, countering deficit discourses about marginalized learners and offering a vision of coding education grounded in "antiracism and justice" [12, p.36].

One of the first inclusive pedagogy strategies we noticed was the relatively expansive view of accessibility held by coding workshop organizers and instructors. In our experience, traditional university software engineering education generally thinks of accessibility in terms of compliance with the Americans with Disabilities Act (ADA) regulations or offering instructional material in various modalities. These workshop organizers and instructors considered that, but they also thought about accessibility in material terms. The coding workshops and meetups we studied tried to create more accessible learning environments, choosing locations close to public transit or online platforms, scheduling times to make it easier for participants to be off work or find childcare, making their workshops free or low cost, and providing meals or snacks for participants. Each organizer we interviewed made a point to lower the barrier for entry for participants, considering what factors might make it difficult for participants to attend their workshops and meetups [2].

The next inclusive pedagogical strategy we noted was how coding meetups and bootcamps intentionally centered representation at multiple levels in their pedagogy. Organizers and instructors highlighted the importance of participants seeing people like themselves (for example, women or women of color) at the front of the classroom. Each meetup or workshop also included teaching assistants who were able to share their own journey into the tech industry,

helping participants to imagine how they might take on a similar role. Finally, the coding meetups and workshops also considered representation in their teaching materials (for example, using examples of people similar to the workshop participants).

The third inclusive pedagogical strategy used by coding workshop and meetup organizers and instructors was building frequent opportunities to cultivate community among participants. These meetups and workshops started with activities meant to help participants get to know each other, prompted conversation over meals, and designed learning activities to be completed in pairs and groups with the support of teaching assistants. Workshop organizers and instructors characterized their own learning experience as "a firehose of information," characterized by a "sink or swim" mentality that had left them feeling "isolated" in their software engineering education. Due to these experiences, they explicitly framed their teaching as an introduction to a new community, inviting participants to help shape community standards as they learned. Learning in this context was understood as social, an active process of making meaning between instructors and participants.

Taken together, these inclusive pedagogy practices were designed to equip learners with an affective coding literacy, one tied to student dispositions of confidence. While these non-traditional sites of coding education taught technical skills and functional literacy, they also framed their learning outcomes in terms of student perceptions of confidence.

7. Implications

While our new round of participant recruitment is currently ongoing as of summer 2025, we offer this discussion based on our initial round of data collection, contextualized with relevant scholarly literature.

7.1 Impact on Women's Success

Programs to increase women's participation in software engineering emphasize both technical and non-technical skill development. Women-focused coding boot camps, online platforms, and community programs significantly impact participants' confidence and persistence. Research suggests that creating a sense of community in these settings boosts self-confidence and motivates women to pursue careers in STEM [20]. For example, Black Girls Code provides participants foundational coding skills, preparing them to succeed academically and professionally [26]. Similarly, boot camps like Ada Developers Academy provide project-based learning experiences that mirror real-world challenges, fostering adaptability and critical thinking, as well as reporting that 81% of its graduates achieve full-time employment within six months of graduation, illustrating the effectiveness of its program in bridging the gap between education and employment [23]. Mentorship plays an essential role in women's success transitioning into software engineering careers. Programs like Girls Who Code and Technovation Girls pair participants with mentors who act as role models, provide guidance, and develop resilience [29]. Peer support creates a safe space for encouragement and shared experiences to alleviate women's isolation in male-dominated industries.

7.2 Barriers to Effective Implementation

Simultaneously, non-traditional education programs often face skepticism from employers. Many hiring managers continue to prioritize traditional degrees over alternative credentials, which can undermine the impact of these programs. For example, though Ada Developers Academy has established partnerships with tech companies to validate their training [23], broader industry recognition remains inconsistent. Stereotypes, implicit biases and cultural perceptions continue to affect women's participation in STEM fields. Creating inclusive environments and promoting diversity in software engineering remains challenging. Research indicates that without intentional strategies to foster inclusivity, women may feel unwelcome or isolated in tech workplaces [30]. Furthermore, not all non-traditional programs maintain consistent quality. Other with documented success face challenges with long-term viability, such as Women in Code [31]. These initiatives often rely on local chapters, volunteers, and donations, limiting their ability to expand. The lack of resources or infrastructure make it challenging for such organizations creating systemic change on a larger scale [25], [26].

8. Conclusion

Ultimately, each coding workshop and meetup worked to increase access to coding education by attending to the material conditions of participants' lives. By intentionally centering representation at all levels of the curriculum, workshop organizers actively rewrote narratives that linked coding literacy to a specific identity. Workshop instructors practiced a pedagogy that emphasized active learning through problem-solving, emphasizing a multiplicity of approaches. In these workshops, participants were encouraged to develop their own communities and networks of support and actively work to change the culture of broader tech communities. The coding workshops considered here ultimately offered an introduction to the syntax of various programming languages, and more importantly an affective coding literacy centered on participants' feelings of empowerment [2].

This study begins to highlight the transformative potential of inclusive pedagogy and non-traditional educational environments in addressing systemic challenges and supporting women's success in software engineering. Non-traditional programs can demonstrate that tailored inclusive approaches can significantly increase skill development, confidence, and career advancement for women in tech. They can also create unique opportunities for participants to gain hands-on experience, collaborate with peers, and build professional networks. These organizations can promote inclusive practices and increase women's participation in software engineering by providing financial and technological support through scholarships and stipends as well as provide mentorship programs connecting women with industry mentors.

As such, legislation against any programming related to issues of diversity, equity, and inclusion is of major concern to organizers, instructors, and participants in these programs. Moving forward, our research team seeks to understand how the remaining organizations adapt to this

challenging new landscape to continue to foster a more inclusive software engineering environment.

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