

Motivated and Capable but No Space for Error: Women's Experiences in Contributing to Open Source Software

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Abstract

This article presents the results of a research study about the experiences of women in open source software (OSS) communities. The lack of women in computing professions serves as a cause of social inequity and in this research we develop a nuanced understanding of the experiences of women participating in open-source software. In-depth qualitative interviews were conducted with eleven women representing multiple countries and a variety of open-source software projects. The theory of individual differences in gender and information technology (IT) laid the foundation for data analysis and interpretation. The results demonstrate varied experiences of women, the need for women-to-women mentoring, and the need for presence and enforcement of codes of conduct in the online communities. Women shared their experiences of working in a variety of roles and the importance of all the roles in product development and maintenance. The persistence of women in OSS communities despite the toxic masculine culture, and their interest in improving the environment for other women and marginalized newcomers, was evident from the interviews.

Keywords: diversity and inclusion; gender and information technology; individual differences theory of gender and IT; open source software; women in open source

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Introduction

The gender gap in the computing professions is important to understand and alleviate because it contributes to gender inequity in our society. Statistics show that women tend to be overrepresented in lower-paying occupations such as healthcare, education, and administrative support, and that men are over-represented in higher-paying occupations like engineering and computer science (Chamberlain & Jayaraman, 2017). Computing professions provide high status and financial rewards; if women are not participating in these professions in equal numbers, then this will mean continued lower status for women. Men occupy 74% of the computer science and engineering career paths (Chamberlain & Jayaraman, 2017). The lack of women's participation in information technology disciplines is an area of concern and has been so for a few decades. According to Women in Computing (WiCS), computer science jobs were projected to grow 15% to 20% through 2020, and the majority of these jobs are filled by men. In 2016, the National Center for Women and Information Technology (NCWIT) reported that 26% of professional computing jobs in the U.S. workforce were held by women.

Ensmenger (2012) reported that information technology has become one of the most stereotypically male professions and inhospitable to women. In February 2018, U.N. Secretary-General Antonio Guterres, in his speech on the International Day of Women and Girls in Science, called for concerted “concrete efforts to overcome stereotypes and biases that dissuade women from pursuing careers in STEM” (Shein, 2018, p. 20).

Within information technology, lies Open Source Software (OSS), and this research study is set in that niche. OSS refers to software for which the source code is accessible free of charge and the distribution, modification, and adoption of the source code is governed by licensing provisions from The Open Source Initiative (OSI). OSI is a global nonprofit leading authority on OSS¹.

Participation in OSS has been a major area of research for many decades, with various data outcomes having shed light on the motivations of OSS developers as well as on participation barriers that exist in OSS (Steinmacher et al., 2015; Mendez et al., 2018). For example, Steinmacher et al. (2015) showed that 82% of industry newcomers dropped out of the profession after one contribution to Apache Hadoop, an OSS project. In recent years, the interest in understanding and improving diversity and inclusion in OSS projects has become a key issue to ensure the successful development of these projects. The barriers to participation are varied and complex and impact women exceedingly more than men. Mendez et al. (2018) found that 83% of the barrier categories for participation in OSS have a gender-biased facet to them. Terrell et al. (2016) mined GitHub² projects and their results revealed that men's and women's acceptance rates for project participation were lower by 12% when the gender of the women was known. Overall, women's participation rates in OSS are no more than five percent, and that number has been stagnant for decades (Singh & Brandon, 2019; Singh et al., 2021). However, some sources report that a more alarming two percent of OSS developers identify as women (Ghosh et al., 2002; Robles et al., 2016; Singh & Brandon, 2019).

We believe that a silent problem with OSS project participation rates among women lies in how projects may be defining the term, “women,” or “woman,” or “gender.” Thus, in this study, we define gender as a self-determined identity based on one's own experience, as opposed to a more traditional definition of sex being the identity ascribed to an individual, based on the appearance of genitals at birth by a medical professional. Our approach is based on guidelines from previous research which assert that taking gender as a binary variable discriminates against individuals who do not define themselves as men or women (Nowakowski et al., 2016; Frohard-Dourlent et al., 2017). Our position is also aligned with gender intersectionality theories that help us to better understand the nuanced differences within people's gendered experiences along the continuum of femininity and masculinity (Trauth, 2013).

Therefore, our study takes the theoretical approach that the “one size fits all” solutions to improving women's participation in OSS will not work, for women have diverse experiences. Not all women face the same types of barriers or have the same experiences. The recognition and acknowledgment of varied life experiences are essential to identifying and rectifying any problems that women in general face because of their gender or intersectionality. The purpose of this study is to understand the varied experiences of women who participate in OSS communities. The goal was to understand and learn from the experiences of these women in order to better support and empower women who would like to join OSS.

Theoretical Foundation

Research about gender and Information Technology (IT) has been around for a long time, and many researchers have studied the challenges faced by women in the technology industry. Ahuja (2002) did a review of gender literature to propose a model of the barriers faced by women in the IT field. According to this model, a combination of social and structural factors influence a woman's career choice, career persistence, and career advancement. The structural factors include the culture of the field which is ripe with stereotypes and masculine influences, a lack of role models to provide examples of success in the field, and a lack of the kind of mentoring critical for advancement. The social factors include social expectation related to gender roles, work-family conflict, incompatibility between work and family, and lack of integration into informal networks within organizations. This model has led the way for many subsequent research studies that have advanced our understanding of this combination of factors (Adya & Ksailer, 2005) as well as studies that have expanded upon this model (Armstrong & Riemenschneider, 2014).

Ethnographic research conducted in OSS (Nafus, 2012) has highlighted how women receive harsh treatment in OSS communities and concluded that OSS is not so open for women. Many women in OSS experience "constant and extreme" sexist behavior. Furthermore, Nafus (2012) explores how the concept of 'openness' is constructed in OSS communities in such a way as to exclude many women from important positions and activities. For example, code contributions are tied to the individual agency of the developers, who are mostly men and engage in what Nafus calls "vociferous defense" and "highly masculinized, aggressive online talking". Nafus (2012) provides insight into cases where people contribute a lot to the code, but do not engage in flaming wars³, are considered less knowledgeable in the community which makes aggressive behavior a normalized and expected mode of communication among developers. Beliefs about the role that gender plays in coding (e.g., a supposed "gender-blindness"), norms governing communication and how these function in the legitimization of specific coding achievements, and other factors lead to a situation in which women are excluded. This article goes in-depth to explain how flaming wars are carried out until one person backs down—a process that favors toxic masculinity. These type of flaming wars is what often leads women to leave communities (Nafus, 2012; Singh et al., 2021; Jane, 2015). Recent research shows that women of OSS support each other and use governance tools, such as Codes of Conduct and Community Councils, to address discrimination and harassment they encounter in OSS (Ford et al., 2017; Singh et al., 2021).

Research shows that diversity and inclusion in OSS communities positively affect the productivity of the community (Rock & Grant, 2016). Vasilescu et al. (2015) report that when women participate in OSS communities, the communities are more productive, and show that diversity is important because productivity and turnover of software development teams are affected by team diversity. They conclude that when forming or recruiting a software team, increased gender and tenure diversity are associated with greater productivity. In terms of the experiences of women, Vasilescu's (2015) note that the women OSS developers report experiencing "imposter syndrome" and it was observed that "men monopolize code authorship and simultaneously de-legitimize the kinds of social ties necessary to build mechanisms for women's inclusion" (p. 39).

In an in-depth study, Archives of Our Own (AO3), Morrison et al. (2016) present valuable insights into an online community designed and built by women who learned computing skills in the process of creating this system. Morrison et al (2016) demonstrate participation in the community through the theory of legitimate peripheral participation and show the importance of context

for engaging women in computer science. The authors observe that an advantage for AO3 also became the challenge when a few very dedicated women programmers led the process and served as experts to users and novices. These experts mentored and trained newcomers, which increased their work significantly; therefore, the authors caution participants of other such communities to be cognizant and not get overburdened by the potential amount of work needed in mentoring and training new members. They propose solutions for designing such communities with an infrastructure for training, and to take into consideration the theories of distributed mentorship so that the experts in these communities are not overburdened. The research also proposes that learning technical skills for underrepresented groups in the computing field would be more successful if it is embedded in a meaningful context for the participants, as is the case of women participating in AO3.

Trauth (2013) conducted an in-depth literature review detailing the use of gender theories in the past twenty years from eight main Association of Information Systems journals, spanning 132 articles. She grouped the theories used in these publications into three major categories: essentialist theories, social shaping of gender theories, and theories of gender intersectionality. Essentialist theories assume opposite characteristics in males and females. They also conflate gender and sex. The research using these theories highlights the supposed inherent differences between the binary categorization of men and women. The assumption is that underlying biological and psychological differences lead to different experiences for men and women. The research that employs the social shaping of gender theories assumes that the social experiences of men and women determine the observed differences between them. In the context of these theories, males and females are two homogenous groups, and all men or women will experience the same social shaping through their cultures. According to Trauth (2013) this approach is based on the idea that women develop certain roles and dispositions in the world because of their experiences, which are the same for all women, and, similarly, all men develop in the same way. In this theory, men and women are large homogenous groups. Gender intersectionality theories take a more nuanced approach. They do not treat gender as a binary construct, but rather, consider biological sex along with sexual identity, sexual orientation, race, and/or ethnicity. These theories also differentiate between gender research and gender differences research. Gender intersectionality research gives insight into the different experiences faced by people of color (particularly women of color) and gay or transgender people: and this is the approach that informs our research. This type of theorization acknowledges the differences in what were considered by the other two approaches to be two homogenous groups of people—men and women.

Based upon all this research the theory of individual differences in gender and IT was developed. The theory took an aggregated but fresh view, wherein women were not seen as a homogenous group, but rather, their identities, journeys, and circumstances were studied to understand why there are so few women in the field of information technology. The theory of individual differences in gender and IT was formed after Trauth (2002) interviewed women IS professionals in Australia and New Zealand. This theory focused on gender differences to develop an understanding of the successes and failures of women in IT. The individual theory of gender and IT has three constructs—individual identity (personal demographics and type of IT work), individual influences (personal characteristics and personal influences), and environmental context (cultural, economic, societal, and policy influences). This theory has been expanded and improved upon in subsequent studies (Howcroft & Trauth, 2008; Kvasny et al., 2009; Quesenberry & Trauth, 2012; Quesenberry et al., 2006; Trauth, 2006; Trauth et al., 2016). And finally, McGee

(2018) expanded the theory by adding leadership style in IT research to the theoretical constructs.

The version of the theory published in Trauth et al. (2016), and presented in Table 1, provided the theoretical framework for this research.

Table 1. Constructs of the individual differences theory of gender and IT

[IDGIT] Construct	Sub-construct	Examples
Individual Identity	Personal demographics	Age, ethnicity, socio-economic class Software development, IS design
	Type of IT work	
Individual Influences	Personal characteristics	Educational background, personality traits, abilities
	Personal influences	Mentors, role models, significant life experiences
Environmental context	Cultural influences	Attitudes about women and IT
	Economic influences	Cost of living
	Societal infrastructure influences	Availability of childcare
	Policy influences	Laws about gender discrimination

Note. From "The Influence of Gender-ethnic Intersectionality on Gender Stereotypes about IT Skills and Knowledge," by E.M. Trauth, C.C. Cain, K.D. Joshi, L. Kvasny, & K.M. Booth, 2016, *The DATABASE for Advances in Information Systems*, 47(3), 16. <http://dx.doi.org/10.1145/2980783.2980785>

The research goals for our study are to investigate the experiences of women in OSS and the role of gender in these experiences. We wanted to know what the women of OSS think about how gender affects their participation in these communities and how they perceive the experiences of other women in OSS communities. We used the concepts of individual differences theory of gender and IT to design our study. The survey questions were created to address each item listed in the sub-concept column of Table 1. For example, demographic information and personal identity sub-concepts resulted in questions about age/gender/education level, and personal identity questions included the field of terminal degree and the OSS community in which they participate. Similarly, survey questions were mapped to all the sub-concepts. An initial survey request was sent to eight women-only OSS listservs. In the request, we asked participants to volunteer for a follow-up interview by providing their contact information (email). The survey request resulted in fifty-eight responses, and, out of this total, eleven women volunteered for a follow-up interview. The results from that survey are being reviewed for publication in a separate article. The results of the follow-up interviews are being presented here. Please refer to Appendix A to view the list of women-only listservs on which the survey request was posted and Appendix B to view the open-ended interview questions.

Study Design

Ethical Considerations

We received Institutional Review Board (IRB) approval from the “Anonymous US R1 University” before recruiting participants for the study. IRB approved the participant solicitation email, the survey questions, the interview questions, and the informed consent form. All the interviewees provided written consent for participating in the interview and our recording of the interviews. Researchers promised confidentiality to the participants and signed confidentiality pledges for working on the interview transcripts. The interview participants volunteered to participate in this research through a survey of women in eight Open Source communities (Appendix A).

The interviews were open-ended, semi-structured, and conducted over the video conferencing software, Skype. In one instance, the interview was conducted over synchronous chat, because the interviewee was more comfortable in that medium. Each interview lasted between thirty and sixty minutes. The broad topics that the open-ended questions in the interviews explored included motivations to contribute to OSS, perceptions of how their contributions are treated by the community, and how women's contributions are treated generally. Some topics that were added during the interviews included first-time experiences in OSS, the roles of communities and community mentors, working with other women, and the need for more research on the topic of women's participation in OSS. (For a list of the specific interview questions, please refer to Appendix B.) All of the interviews were transcribed completely to generate written text for qualitative data analysis.

Data Analysis

The transcribed interviews were imported into the qualitative data analysis software product, NVivo, for conducting a thematic analysis. An inductive and theoretical approach was used to identify themes. The constructs from the individual differences theory of gender and IT (IDGIT) were used to understand themes in the data, and an inductive approach was used to account for data concepts that did not fit into the constructs of IDGIT. Data that did not fit into the constructs added to a new understanding of the experiences of women.

The data analysis strategy (adopted from Braun & Clarke, 2006) included a two-step coding and analysis process. The first step was familiarization with the data and initial coding using theoretical constructs from the theory of individual differences of gender and IT. The initial coding was done by two researchers, who separately coded one interview and then finalized the coding schema for the remaining interviews. For the second step, search for themes was conducted in an organized manner: identifying themes, reviewing their connections with each other, and refining them to remove duplication or repetitive naming. After themes were refined, a few of them were combined to form broader themes, and codes were reorganized to better fit the themes. During this process of combining, themes and subthemes emerged, and better organization was achieved. Theoretical analysis was the basis of this approach, but afterward, an inductive approach was used to code interview excerpts that did not fit into the existing coding scheme.

Overview of Participants

Out of the 11 participants, four were in the age range of 25-34, four in the age range of 35-44, two in the age range of 45-54, and one in the 55-65 age range. They have been participating in the open-source communities in a range from one year to 20 years, with an average participation length of about ten years and a median of seven years.

The geographical location for the participants for this study are as follows: one participant each in Romania, Czech Republic, Norway, Canada, and India; two in Germany; and four in the U.S.

The highest degree these women had attained was a bachelor's degree for four women, a master's degree for six women, and one doctoral degree. All of these women identified themselves as a woman and one identified herself as a trans woman during the interview. In this article, all participants are referred to as women to honor the wishes of all participants.

The highest degrees were in a variety of fields of study, such as computer science, library science, mathematics, electronics, IT, humanities, comparative literature, and art.

The women described their contributions in OSS communities as coding, bug reporting, testing, documentation, promotion and evangelism, packaging, translations, user support, documentation, testing, requirements analysis for feature development, and community building and advocacy.

Results

Data collected from the interviews provided insights into the experiences of women in Open Source communities. The challenges that the women faced, the factors that helped their integrations into these communities, and the benefits of participating in OSS communities were discovered during the interviews and the analysis that followed. The analysis of the interviews revealed themes and sub-themes as presented in Table 2.

Table 2. All themes and subthemes

Themes	Sub-themes
Underrepresentation	
Initiation into OSS	First experience Welcome person Newcomer advice
Integration into OSS	Experiences - Neutral, positive, and negative Role of mentors in success
Superfluous labor	Quality of work Proving worth Given "women work"

Skill sets for OSS	Not only technical skills Personality traits Characteristics for success
Community actions needed	Code of Conduct Safe places for women Allies needed Advice for community

Motivation

The results are organized according to the themes and sub-themes of the theory of individual differences in gender and IT (IDGIT) instead of being attributed to individual women under pseudonyms because participants raised a valid fear of this data not being confidential if we identify a woman from a country working on a particular software. The reason being that some of them are the only woman working on that software in their country, and they are afraid to attach any quotes to themselves for the fear of losing their anonymity and confidentiality of their responses. Therefore, the differences in individual experiences will be reported in this study but not attributed to specific individuals.

Underrepresentation of Women in OSS Communities

Not surprisingly, all the interviews revealed the theme of the underrepresentation of women. All eleven women confirmed the lack of women in their immediate environment, and a few explicitly expressed a sense of isolation in the open-source communities. The following interview excerpt indicates some of the frustration that women feel as an underrepresented group.

“One thing I always hate is that they point me out all the time, ‘Oh, you’re a female. What’s your opinion?’ Like I’m some kind of a dinosaur in the room, and I have to have an opinion because I’m a woman. And I have to represent the multitude of women that are not in the room. No, I’m not representing them. They should be there with me. I think, again, almost equally, but because we are missing so much in numbers, we lack opportunities and presence, definitely.”

This quote shows how women who are present in OSS communities are often asked to represent “all” women, a burden that is often shared by minorities or marginalized people. Not only do they have to deal with the isolation, but they are often made the voice of everyone who has been excluded. This singling out and expectation to represent all women, increases the labor required of marginalized people.

The next comment highlighted the issue of misleading statistics presented by technology companies regarding women employed in the technology sector. The number of women in technical positions in technology companies is extremely low, but, as the number of women employed includes women in all departments in a company, the statistics presented by the companies are inflated. The actual number of women in technical positions is lower than the reported statistics because the quoted statistics include women in all departments in a technology company. One respondent explained that the statistics quoted are actually about the total number of women employed by technology companies, and thus includes women who work

in human resources or other non-technical areas. This respondent works in a large technology company and says that she does not know many women in technical positions in her company. She said:

“I actually know only one girl whom is actually in a software developer position.”

All of the women interviewed agreed that women are underrepresented in the tech sector, and OSS, and they observed specifically that few women occupy software development roles. Their responses to subsequent questions offer insight into what aspects of OSS communities contribute to this gender imbalance.

Initiation of Women into OSS Communities

The interview results demonstrated that the experience of participating in an OSS community for the *first time* is one of the most influential factors in whether women stay and continue to participate in the community in the future. The advice that the women gave for newcomers, who would like to contribute to OSS, focused on persistence and strong personality traits. The role of the person or group that introduces a newcomer to an OSS community is also very important in creating a positive experience for the newcomer.

First Experiences and the Role of the “Welcome Person”

The role of the first person who worked with women had a very positive impact on their experience. The following excerpt from an interview shows that despite the actual work being intimidating and labor-intensive, the woman was positive about the overall experience.

“The first open-source project I contributed to was actually a pretty big project. It was for SoftwareName. It was kind of intimidating, and, in order to get the change accepted, I had to write tests. And this particular part of the codebase wasn't getting tested, so I had to write 50 lines of test for a one-line change basically. But the people that were working with me on it were very patient and very good at walking me through the whole process. So, in that regard, it was very positive.”

This quote is important because it demonstrates that it is the socialization of newcomers that is critical to their experience and not necessarily the difficulty of the first task (Steinmacher et al., 2015).

The importance of meeting the right people at their initiation into the OSS community was expressed by multiple interviewees. The role of the first person to introduce the women to the OSS community was integral to their experience. This person did not necessarily end up being a mentor for them. Sometimes all that the welcome person had to do was to introduce the women to the community and then women independently participated in the community. Still, their introduction made participation easier for the women. In the following two instances, the welcoming person was male and helped the women's initiation into the OSS community.

“It just went really nice and I immediately met the right people at the right time. The first person that replied was John⁴, who is a new council member as well. He's just the best person that you can meet. He's really nice, patient, and will break his back to answer your questions. If he has to, he will write a whole essay for you to get the point. He's very nice.”

From this quote, we can see that the first positive experience for this woman led to her staying in OSS and being a successful contributor. The role of allies is highlighted in this excerpt. The next response talks about having a positive first experience, but also discusses the role that leaders at different levels can play. Allies and leaders together can create a memorable positive experience for a newcomer in the community, which would impact the retention of women in OSS, as shown by this interviewee's experience.

“One of the absolutely most important things, I think, was that the leader of the workshop was experienced in making things comfortable for everyone. He sort of set the tone, even though there were people around who worked together before, coming from a lot of different countries. You may know the name (Max), He was there. I didn't know him. I didn't know his face. I really didn't recognize his name. This was back when I was really fresh. He was part of the crew there, and he's famous for being nice, too. He's famous for being very nice to women. Again, I think it's because (Max), who led the workshop, was really experienced. Simple.”

Next, we look at some examples of negative experiences that the women faced when they joined an OSS community. Some women pointed out that their first encounter with the OSS community was uncomfortable because of their gender and that they had to find people to work with who would not make them uncomfortable for being a woman interested in technology. As the following interviewee explained, being complimented is not unwelcoming, but it does distract women from being comfortable in that environment.

“When I got involved in open-source for the first time, I discovered that being a woman interested in technology and computers, I met men who thought I was really cool, and then they sort of were expecting, “Whose girlfriend are you going to be?” They were like, “We're thirty guys! Surely you must be interested in one of us! Because we're interested in you!” Of course, it's nice to feel attractive, but it also felt very uncomfortable, because that was not why I was there. I was not there because as a woman; I was there as interested in technology. And they failed to see that, which made me uncomfortable, and I ended up finding a few people that do understand that I was interested in the technology (and not because primarily, I was a woman), and I grew from there.”

This excerpt highlights one of the most common types of harassment that women deal with in the technology industry (Women Who Tech, 2020), and it is no surprise that harassment happens to women in OSS too because OSS is very skewed in women representation and the community rules either do not exist or are not enforced (Singh et al, 2021). This is the type of problem that can be reduced by awareness among OSS contributors and establishing Codes of Conducts for communities to avoid this type of normalization of unwanted attention.

In the example above, a positive first-time experience with OSS involved supportive community members and mentors who reached out to new OSS participants in a way that made them feel comfortable. In contrast, the woman with a negative first-time experience described receiving negative, uncomfortable attention because of her gender. While she continued in OSS, she had to put in extra effort to seek out community support.

Newcomer Advice for Joining OSS

The interviewee's key advice for newcomers included ignoring any harsh responses from the community and not taking any individual's hostile behavior personally. It was highlighted that sometimes harsh responses from the community were not necessarily the result of these women's gender or quality of work, but rather, just a common culture of the "techie guys." It is this culture that Nafus (2012) refers to as the culture of "openness" that has been cultivated to prove the worthiness of software code but leads to toxic masculinity and harassment of women.

"My first and biggest advice (I'm not sure if I have many others) would be not to take things personally at the beginning. I consider that if they were to face hard times, they should tell themselves the others have misconceptions, they don't know what I'm capable of, and I should just continue doing what I'm doing. And, of course, if you think at that point that you are not doing something good, ask for opinions and feedback. But again, don't take it personally, like, "They said I'm wrong?!" if you submit a batch or other document or design and somebody old enough or grumpy enough will say, "Oh, that's bad. Stop it." You should not stop at all. Say, "Thanks for the feedback, let me know how to improve," then continue."

As we can see from this excerpt, the women who succeed in OSS have to develop a thick skin, handle rudeness, and people challenging their knowledge. These experiences often lead to women developing imposter syndrome and not believing that they belong in these communities. This type of toxicity becomes a barrier to continued participation, especially for women who are new to these communities (Steinmacher et al., 2015).

One interviewee discussed the importance of resilience and advised newcomers to tap into their motivation for participating in the OSS community. As a coping mechanism, she suggests "detach yourself sentimentally" from the situation showing the understanding of the emotional burden that a negative experience can be for a newcomer.

"Persistence, yeah. And don't let yourself get blocked by a situation. Try to get the constructive part and then continue. That's why I said don't take it personally and try to detach yourself sentimentally from things that you do. Because as a woman, or a man, you have feelings and you get affected by them, but starting to work with unknown people whose background you don't and are maybe having a bad day and are just bad to you because they had to let it out or something and you were in the wrong place. Don't take it personally. You are not there to please them. You are there to do something that you like. At least I hope you like it, anyway."

Several of the interview participants pointed out that newcomers should always remember that there are many projects out there and that their experience with one project or project community should not deter them from exploring other communities. Many OSS projects welcome women in their communities, so the newcomers should find those and participate in projects that identify themselves as encouraging diversity and inclusivity. Newcomers should "be persistent" in their participation and selective in the projects to which they choose to contribute.

"I do think that the open-source world is much bigger than you think, so if things don't fit right in one place, it doesn't mean that the whole world of open-source is not for you. It just means "find another project." Simple as that. There's so many projects. Find

another one. That's one of the fun things about open-source; it definitely comes in every flavor."

In future research, the authors of this study are working on developing evaluation criteria for OSS communities through which the communities can be categorized according to their support for women, marginalized populations, and commitment to diversity.

When we asked the interviewees about their advice for women who are interested in participating in OSS communities, they shared several ways in which they thought it would be best to start. The following excerpt shows that OSS contributors do not have to always be technical because they can contribute to non-technical aspects of OSS, such as translation.

"Starting out with translation is super easy, if you're not very interested in coding. If you are interested in coding, start there. It's a great way of starting to read code and seeing how things are structured, and you learn a lot from it. You can also submit patches, so you are contributing to the community, not being an island. You don't have to create this whole big thing alone."

Another woman shared her experience of starting as a contributor on email lists and then being invited to be a "committer" showing how women can start with a non-technical activity and can also participate in technical work.

"I think I started and I started figuring out stuff, and I was answering questions on email lists, and then when I returned to SoftwareName with this job, which was about four years ago, they very quickly invited me to become a committer."

The next piece of advice is for women to not be intimidated and think that they are not capable of contributing like a man who is just starting.

"Another thing that women often do, they have this intimidation thing. They have this impostor syndrome. So being aware of that would help, I think. Recognize that the guys start out as stupid as updaters."

The next excerpt laid the groundwork for the discussion about the concept of safe spaces, where the interviewee recommended that women who want to join OSS communities should join women OSS-related groups, which would be more supportive spaces that could also provide networking opportunities.

"Also, I think it's great being able to meet people in person, so maybe point to meetups or volunteer organizations. So the best thing they can do is to join all the women in foss /computing groups and geek feminism groups. there are groups like Sisters too."

This idea of safe spaces for women in technology has found support with many initiatives across technology communities and is receiving interest from researchers as well.

The aforementioned advice emphasizes that women who want to enter OSS should be resilient against negative experiences. Women are instructed to toughen themselves against mistreatment and rejection and to work hard to find a position and a supportive community. Not all of these recommendations relate directly to dealing with gender-based discrimination, but all involve women doing extra work to make up for shortcomings in the OSS community environment.

Integration into OSS

After joining the OSS communities, women reported a mix of positive, negative, and neutral experiences. Some examples of these varied experiences of women in OSS communities are presented below.

The positive experiences highlighted the absence of any discrimination, a culture of learning, and not being afraid of failing.

“I never felt discriminated. I always felt that I’m empowered to do whatever I want. I contributed from code to organizing events. I always felt that I can do anything, no matter my gender nor my origin. I felt that I’m allowed to try and fail.”

“I have really no complaints. It was generally a nice experience. Everyone is very welcoming and helpful.”

One interviewee expressed her excitement about learning how to contribute and share within an OSS community. The collaborative aspect of the community was a positive for this interviewee.

“I did start out with translation. It’s super-fast to get into. And then you sort of discover the whole structure that “anyone can contribute,” and you are taking someone else’s work, and you’re basing your work on someone else’s work, which is a fantastic experience when I had it. It’s like, “I actually get to do this? I don’t have to start from scratch?” We can actually share. It’s not mine, it’s not yours. It’s ours. That was nice.”

Among the challenges that the women shared as part of their experiences of regularly contributing to OSS communities, gender bias was a major concern. The interviewees felt that women were always met with different expectations and were, by default, considered less technically proficient.

“Basically, everything was really down and like I don’t know what I’m doing.”

One interviewee said that she has witnessed that women encounter hostility and general condescending responses from men in many of the OSS community online forums.

“I’ve observed that a lot of the forums and email lists, when there’s a discussion breaking out, and someone calls on (pardon the expression) bullshit or says that you’re over the line and they will attack someone just because of their gender. Very often, any community online will claim that they are gender-neutral. They’re not. They’re not at all. It’s very obvious that women are met with different expectations, and they are met with a distrust, unfortunately.”

The hostility from men in the OSS community is damaging to the morale of the women participating, and in addition, it leads to feelings of isolation and normalization of this behavior. One interviewee articulated that if no one speaks out against the hostility, it makes the environment worse for the women who observe this response. When this type of hostility is experienced, allies must react to the situation, to handle the situation at hand, and also to send a message to the observers that this community treats women fairly.

“It’s met with a “Are you sure that this is good enough?” This one really angry guy dominates the group a lot. And he’s like, “We’re not agreeing with him.” Yeah, but you’re not protesting either. Which creates an illusion of online communities being more hostile than they probably were meant to be or are seen from the friendly male perspective. Bad eggs really get to pester the place and be annoying, and nobody really stands up to them while the women are around. But when things are good, it’s nice. It’s very nice. It feels like a double victory. But it’s very lonely when you’re battling these one or two or three annoying guys, and nobody supports you. Nobody steps up, and especially if they don’t agree.”

One interviewee stated that women, including her, face misogynistic discriminatory behavior in their interactions with OSS communities.

“I’ve certainly heard stories from other women through other communities, and that’s something I have run into directly where it was clearly misogynistic activities.”

Women are often left wondering if their contributions are being scrutinized or rejected because of their gender. The following excerpt from an interviewee who is established in her community, and has participated successfully for a long time, demonstrates the lingering impact of perceived discrimination. This type of reaction has often been referred to as imposter syndrome by many researchers and has been observed and documented in the experience of women in IT.

“There was one incident when I had a pull request up against a library. It would’ve been a fairly small change that would’ve added a lot of new functionality, and they said basically “we don’t want to do that”. I’ve always wondered if I just had a male teammate put out that pull request instead, and I think it maybe could’ve gone through. I don’t know. I don’t have any way to know what exactly the circumstances are.”

When asked if they believed that women were treated as equals to men in the OSS communities, all the interviewees said that women are not treated equally and have to work harder to get recognition. Even if they felt that they were personally treated as equals in their respective communities, they said that women, in general, are not treated as equals.

“No, they are not treated equally. Misogyny is too common. Even when it comes to inviting speakers, I have seen event organizers of other [UserGroupName] stick to men alone. In mailing lists, many instances of misogyny can be found”

When asked to describe examples of misogyny that they have observed or faced, one interviewee explained the inherent bias that women face and the pressure that it puts on women to always be right. She saw it as unfair because men are allowed to fail and learn from their mistakes while women are harassed and condescended to in the same situation.

“Oh, she’s a woman. She doesn’t know how to code. That’s why she did something wrong.” Or if they would bring a challenge to me and I would say from the beginning, “I don’t know. I need to document myself.” They would say, “Of course she doesn’t know. She’s a woman. She doesn’t know how to code.” But if a man does that, he’s allowed easily to do his search.

When asked about differences in the quality of contributions between men and women, one interviewee explained that she expects better code from women because she believes that a

person from a minority has to be outstanding to have a chance to participate at a higher level in the project. She stated that a man could be average and still make it to the next level of the project hierarchy. This type of extraneous, often vexatious labor, is part of the daily experience of women in OSS.

“Mostly I see men’s code, you know. Did I actually see code from a woman? I don’t know. I’ve seen ideas from a woman. I have this theory that if you’re from a minority, you can usually expect a higher standard or better than the average guy, but this is because you stick out. It just comes from the way the process works. If you’re just an average or below average programmer as a woman, you’re not going to be a committer in a project. You might be a committer in a project as a man, because there’s just a lot of them. The few that are there are probably better, but that’s just by the nature that they’re the survivors.”

As was the case with their first-time experiences, the women interviewed described a positive experience of integration into OSS as a matter of a supportive community environment that facilitated learning and the enjoyment of their work. Negative experiences were characterized by community hostility, including gender-based discrimination. The women recognized that this discrimination was common, even if they had not experienced it personally.

Role of Mentors

All the women who were interviewed echoed that having a mentor would be very useful for participating successfully in an OSS community. Mentors were mostly described as experienced contributors who can guide newcomers regarding social interactions, taking criticism and utilizing it well, and feeling comfortable contributing. This mirrors the findings from previous research about the value of mentorship for marginalized populations.

“It helps a lot to have a mentor of some kind. A one-to-one mentorship. This mentor would be able to answer the questions. More than a colleague, like a friend, and a person you wouldn’t be afraid of. Someone who is friendly to approach if you have a problem, and they can help.”

In the next quote, we see how the presence of mentors works in cultivating allies and sensemaking of discrimination and harassment. Mentors impact the mentees’ experiences and also emulate behavior for allies to follow.

“Mentors. I think that is a good thing, again because you need someone to have your back. Sometimes you don’t always want to talk on the open forums, and it makes it easier to handle critics in a sensible way, because sometimes the critiques that you’re receiving are justified.”

The participants in this research envisioned a continuing role for mentors, which is similar to the role that mentors can play in welcoming first-time women participants into OSS. In both cases, the mentor is someone who helps improve the experiences of women participating in the OSS. In the examples from the interviewed women, this help included dealing specifically with community-based problems, such as harsh criticism or mistreatment.

Superfluous Labor

One theme that appeared consistently in all the interviews was this aspect of additional work that the women must do to be successful in OSS communities. Women reported that either they have done this or consistently witnessed women doing this additional work. The superfluous work does not concern the code, or the main contribution itself, but rather concerns making a case for that piece of work—that is, proving its accuracy, legitimacy, and value. While doing this superfluous work, women also feel the pressure to be perfect and not make any errors while contributing. The gender-biased approach of men makes this superfluous labor a necessary part of women's contributions.

“The amount of work invested, I think, is bigger in a woman. I still feel that, even to do something, we have to prove ourselves all the time. The code will speak for itself, but before implementing it, you might need to express your opinions to show why that would be the best solution. And at that point, I think we need to be perfect all the time, not to give space for errors, because they will take advantage and will say, “Oh, she's a woman. She doesn't know how to code. That's why she did something wrong.” Or if they would bring a challenge to me and I would say from the beginning, “I don't know. I need to document myself.” They would say, “Of course she doesn't know. She's a woman. She doesn't know how to code.” But if a man does that, he's allowed easily to do his search. So I think for us, it's always a struggle to do perfect. Even if we know we are capable, in our minds, we cannot allow ourselves space for error, or research, or for thinking or brainstorming, maybe. Because we feel we would be discussed”

“Because you have to work harder to get your point across.”

Women reported having observed other women doing this superfluous work in addition to their actual work and trying to prove themselves in almost every interaction. One interviewee also reported that they were often judged as being at a much lower skill level than they are.

“They come in with a higher quality, or have done more research, or the emails from women are “this” long and very well-founded, and the guys are like, “I made this thing. It should be super.”

This type of experience could potentially be the reason for women not wanting to reveal their gender or identity in their profiles. As one interviewee put it very succinctly, she wonders if her work would be easily accepted if she chose to hide her identity.

“I often wonder how much easier it would be to get stuff done if I had a profile that didn't make it obvious what my gender was.”

Even the women who are successful, and are working hard to contribute to OSS projects, deal with this sense of not being treated equal and their contributions not being taken on merit because they are a woman. In the example below, the interviewee felt that her gender might have been the cause of her not getting a job in OSS.

“I sort of wonder after the fact if that would have happened if I were a man. Again, there's so much that you can't put a finger on. I did apply within here for a job working with open source stuff, and they did end up taking one of the committers, who was

outside. On the other hand, again, would they take me more seriously if I were a man? I thought I made good impressions.”

Overall, the women interviewed had the sense that women in OSS were required to put in greater effort to achieve the same degree of success and respect as men. Beyond their technical work itself, they must defend and justify their work much more than men in a similar situation. This sense of doing extra work affects the women even if they do not describe experiencing open gender-based hostility.

Characteristics for Success

Across all the interviews, there were many comments about what women felt made them successful in the OSS community. Their comments about how other women should interact in the OSS environment also highlighted characteristics that they considered were important to succeed. They used words like “brave,” “stubborn,” “persistent,” and “detached” to explain their journey and characteristics for success.

In the following comment, the interviewee expresses her awareness of the pressure that is put on women when they are told to be braver, but she does not see any other way to succeed in OSS.

“Just be braver.

It’s sort of rude to just say to women that everything would be fine if women were just braver, but I think it’s a necessity until the world saves us.”

Another interviewee indicated that being stubborn helps her succeed in OSS.

“I’m really stubborn. I don’t want to admit anything. I don’t give up.”

One interviewee explained that she believes that detaching yourself from your work and not taking things personally is important to succeed in OSS.

“Don’t take it personally. You are not there to please them. You are there to do something that you like.”

“Detach yourself sentimentally from things that you do.”

These traits are all useful for dealing with the critical and sometimes hostile environment of OSS, but particularly for dealing with the negative experiences of OSS that are specific to women. Bravery, stubbornness, and resilience to criticism are useful for enduring both gender-based hostility and the superfluous labor required of women in OSS.

Skill Sets for OSS

One theme that emerged in all the interviews was the importance of all skill sets within OSS communities. The interviewees emphasized that an OSS community is not just about coding. Therefore, anyone who is interested in contributing should not hesitate solely because they are not coders. All skill sets are needed and are important for a successful product. This

recommendation goes for newcomers, as well as for the communities, who should value the different skills that are needed to create and maintain their software and community.

“We need different people to have a successful product. I would try to emphasize that there should be a place for everything. If there is no place for documentation for less technical people, we should make a place for them, because they all deserve a place.”

“Because really, without documentation, the user won't understand us if we are not documented, right? The user won't understand the program if it is not well-designed or well-tested.”

Among these different skill types, the interviewees focused particularly on communications skills, such as documentation and translation. They highlighted these skills both to encourage less technically-oriented people to get involved in OSS, but also to reinforce the necessity of good communication to participants and user experience of OSS products.

Role of the Community

The interviewees recommended several things that the OSS community can do to support women participants. The recommendations for the community ranged from being patient, helpful, open, and friendly to clearly articulate a Code of Conduct to support women.

“And besides patience, always remember that those in open-source are trying to do something good from their volunteer time without any benefits like money. Probably, someone at home will ask them, “What do you get in return?” They won't be able to say money or anything material. So try to at least be nice, and if you can, of course, help.”

“I'd say that it's important to be friendly and not discourage someone. Basic people management skills are necessary.”

Companies should be committed to increasing diversity and also allowing and supporting women to spend time with newcomers in mentor roles. Mentoring and integrating newcomers is important for a community to be diverse and innovative. If the organization realizes this, then they should be compensating women who take mentorship roles so that it does not become a burden to the mentors. If companies do not support this type of collaboration, then they are not being supportive of women newcomers.

“I could not do that on company time. If companies were willing to let whatever small number of women they have do it on company time and not let it slow them down, and it would be counted toward a career achievement.”

“Companies have to have a serious commitment to increasing their numbers.”

Codes of conduct help guide communities. They allow women to seek help and allies to point the code of conduct out to anybody who is violating it.

“I think it's great that a lot of big conferences and larger open-source projects are adopting code of conduct. I think that's a really good place to start. Just to have some point on contact with that, which I suppose would be part of the code of conduct, would

be good. The code of conduct is to have someone to reach out to if something does go wrong.”

The suggestions made by the interviewees reflect their common emphasis on a supportive community, as expressed in their other responses. They encourage the OSS community, in general, to be more supportive and patient with new participants, and particularly to support mentoring. They also recommend codes of conduct as a way to counter more direct forms of gender-based discrimination. Both of these types of suggestions serve to counter the community hostility that most of the interviewees identified as a key cause of negative experiences in OSS.

Discussion

The main findings from this research are summarized according to themes in Table 2. In this section, we use the IDGIT constructs to review the key findings. Table 3 extends Table 2 with specific examples from the results and showcases the impact of themes and sub-themes from the interviews.

Table 3. All themes and subthemes with context from the results

Themes	Sub-themes	Impact and Examples
Underrepresentation		Isolation, Have to be the voice of “all” women
Initiation into OSS	<ul style="list-style-type: none"> • First experience • Welcome person • Newcomer advice 	<ul style="list-style-type: none"> • The social aspect of first experience more important than technical difficulty • Leaders and Allies both play a role in welcoming • Newcomers should research which community to join as that will determine their experience and chances of success, detach yourself, do not take it personally, tap into your “why”
Integration into OSS	<ul style="list-style-type: none"> • Experiences - Neutral, positive, and negative • Role of mentors in success 	<ul style="list-style-type: none"> • Not treated equally, Experienced and observed harassment • Useful as a mentee and observer
Superfluous labor	<ul style="list-style-type: none"> • Quality of work • Proving worth • Given “women work” 	<ul style="list-style-type: none"> • Women have to consistently do extraneous work to prove their worth

		<ul style="list-style-type: none"> • By default assumed to be non-technical; given work like events management.
Skill sets for OSS	<ul style="list-style-type: none"> • Not only technical skills • Personality traits • Characteristics for success 	<ul style="list-style-type: none"> • Contribution does not have to be technical • Resilience, thick skin, persistent, stubborn
Community actions needed	<ul style="list-style-type: none"> • Code of Conduct • Safe places for women • Allies needed • Advice for community 	<ul style="list-style-type: none"> • Clearly articulated code of conduct with enforcement information • Create spaces where women are comfortable to join and learn
Motivation		Remember your "Why"

The individual identity construct, and specifically the type of IT work, was very helpful in understanding the experiences of these women. One participant was very comfortable and confident in her initial contributions as a translator, and it allowed her to learn and “graduate” to tasks that are more complicated and higher level in the project. Another participant explicitly stated that contributors, who are not technical contributors, are seen as contributing less or considered less important, which should not be the case because the software needs all types of contributors to be successful. This highlights the difference in approach among these women for the same aspect of contributing.

“One thing for us to get down to is different levels of technology. One thing that I hate (that’s a strong word to use; I’m sorry I’m using it): In everything I do, there is the misconception that if someone is not technical, they are less worthy, which is not true. Because really, without documentation, the user won’t understand us if we are not documented, right? The user won’t understand the program if it is not well-designed or well-tested.”

This example also shows that although both women saw the non-programming roles in the OSS project as important, they had a different expectation from doing that role. One wanted to “graduate” to more complicated roles and the other one wanted equal recognition for all the contributors to the project (irrespective of the role). This is tied to the individual identity construct and explicates the differences among women, another key point to consider when designing solutions for women in OSS. Trauth et al. (2016) discuss that technical and no-technical skills are becoming a part of gender identity for women. Women imbibe the culture of their environment and reflect the stereotypes of “masculine work” versus “women’s work;” we found the same thing in our results where some women internalize a hierarchy in the work needed for maintaining a successful project. If they contribute to what is considered “woman’s work” will they ever see the success that is equal to the success that men find in these communities?



The individual influences construct was critical in understanding the approach of women towards the unfavorable environment in OSS, and the personality traits construct helped in understanding what characteristics these women consider necessary for succeeding in an OSS community. Interviewed women used words like stubborn, unfazed, and detached to express their approach to participating in the community. Most of the women believed that there is negativity in online communities, and they choose to “not take it personally” and be persistent in continuing to do what they love to do (contributing to OSS, coding, etc.). Similarly, for newcomers, the key pieces of advice about personality traits were to be brave, to be persistent, and not to be deterred by negativity. The personal agency that the women displayed in their work, their interactions, and their approach to contributing is what led to them being successful in their environment. It is well known from previous literature about F/LOSS that there is a “geek masculine stereotype” culture in OSS (Reagle, 2013; Ensmenger, 2015; Menking et al., 2019); our study demonstrates the strategies and approaches that women use to navigate an environment that is created by men and can be unappealing to women. Women have to take the burden of responding and assimilating in this culture in order to participate in OSS communities, either as volunteers or for their jobs. Based on our study, their approach is to become detached and ignore negativity to complete their work. This leads us to question how this distinction between gender-based roles plays into expectations for workplace behaviors? Many studies point out that “toxic masculinity,” flaming and aggressive interactions are part of the OSS community; does that mean that to be successful in these communities women have to become more “masculine” and exhibit these traits in their interactions with the community? Or that they have to take on the “masculine work” to be accepted into the community? The additional emotional burden of “detaching” and “ignoring negativity” as a coping mechanism cannot be inconsequential. Repeated exposure to such toxicity, and the necessity to do this extra emotional labor, could have a lingering impact on the mental health of women.

The personal influences construct helped us to understand the role of mentors, or “welcome people,” who encouraged these women to stay and contribute to the OSS community. The women who met the “right people” when they first started reported a much easier, faster transition and felt like they were encouraged to participate and contribute. Having the right mentor who could help them navigate the technical landscape, and more importantly, the social landscape, and who would stand up for them, made their experiences much more positive. Women who did not have a mentor also believed that having a mentor would be beneficial to newcomers and would make the integration into the community faster. We believe that positive relationships with mentors, allies, and peers are critical for women to thrive in technology communities. Ford et al. (2017) studied women participating in Stack Overflow to understand the influence of peer parity, which occurs when an individual can identify at least one other peer interacting in a community. In this study, the authors discuss that showcasing the success of women, pairing women for guidance, and revealing user identity will all positively influence peer parity and provide encouragement for women to participate in OSS. Our research also shows how women interviewees agreed that having a mentor, and seeing examples of successful women, would be useful for all women. Understanding this concept of peer parity is critical for organizations wanting to implement successful mentorship programs and in helping alleviate “imposter syndrome” for women in OSS.

The environmental construct includes cultural influences, economic influences, societal infrastructure influences, and policy influences. The environmental context construct helped understand the integration of women into OSS. One woman shared how she first heard about OSS at her university as part of an event organized by a local student club. Her experience, as noted

by her (and observed by the researcher), was unique and positive. She enjoyed meeting new people in her environment and attending regular meetups, which led her to continue to work with them and start contributing to other OSS projects. Most of the women reported that they are continually motivated to contribute to OSS because it has become part of their life. They care about the philosophy of OSS. Also, they enjoy the like-minded people they meet, and the social aspect of OSS participation keeps them engaged and motivated. Economic influences could be very easily seen in the number of hours that the women spent in OSS communities. For women who are paid to contribute to OSS, advocating for OSS is part of their job. They thus, understandably, spend significantly more hours contributing than women who volunteer their time.

One woman also expressed that more women would become mentors to newcomers if their company gave them incentives to do so. They do not always want to take time from their work to mentor others. This is an important point to understand because oftentimes marginalized populations have to take on additional emotional and service-related labor to mentor other marginalized people. Organizations need to do a better job of documenting this labor and creating compensation and recognition for this type of work. It is, as a matter of fact, an investment in the future of the organization and should not be the burden of the marginalized people to carry alone. Emotional labor in Wikipedia is explored in depth by Menking and Erickson (2015) where they discuss that women often have “taxing emotional labor” while they contribute to Wikipedia. Menking and Erickson (2015) ask if such emotional labor is indeed a cost for enabling a complex project such as Wikipedia. We see that in our study where it seems like women have to do the extra labor to support other women, and to succeed themselves, even though diversity improves innovation in the organization Rock and Grant (2016). Therefore, should organizations be investing in the marginalized people who do the extra work for them?

The cultural influences construct was visible in the experience of an Asian woman participating in this study. She clearly articulated that she has experienced misogynistic behaviour. In future research, this is an area to further explore and in which to compare the experiences of women from different cultures and different races. Attitudes towards women and IT in culture would presumably impact the experiences of women in IT in that culture, and these attitudes would be different among different cultures.

Most of the women who were interviewed said that the OSS communities that have a code of conduct policy or set of guidelines are the ones that are friendly to women. These are the communities where senior male members or allies will often step up and point out the guidelines when there are incidents that could be inappropriate for newcomers. Research on Codes of Conduct in OSS shows that the presence of these codes, in tandem with visible enforcement of codes of conduct, improves the experiences of women (Tourani et al., 2017; Singh et al., 2021).

Interestingly, in the interviews, several women reported encouraging other women to participate as part of the motivation for joining, contributing, and staying in OSS. Another reason to participate in OSS was to be part of a community of learners to improve their own skill sets. Women said that if the project they were working on was successful, they would stay there and contribute irrespective of the community response. Several women said that they believe in the philosophy of OSS and the good that their software brings to its users, and, therefore, they continue to participate and keep encouraging other women to participate. Women's motivation and competence are not an issue but both aspects are challenged often.

One of the things that were striking in this research was the way women characterized how they approach and how other women should approach contributing to OSS communities. It did not seem like they were contributing to something intellectually but rather seemed more like a daring endeavor. The advice for newcomers included comments such as “you have to be brave; you have to be strong; you have to ignore; you have to be extra smart; etc.” This kind of advice made the author wonder why participation in a community where you are contributing your skills, often without pay, should be such a crusade. In addition to the knowledge and skills that these women bring to the community, why do they also have to do this onerous labor of managing a hostile environment?

Limitations of the Research

As the authors continue to understand and explore this complex issue, we are aware of the limitations of this research study and plan to address some of these issues in future research. We acknowledge that this research presents results of interviews with women who volunteered to participate in this research, and therefore there is a self-selection bias in the results. We would also like to interview women who have left OSS communities, because without their perspective we cannot completely understand the experiences of women in open source. In the results we present, we do not presume that these experiences are unique to women, but rather we present these as the experiences of women who participate and chose to stay. Some of these experiences are very likely applicable to all newcomers, irrespective of gender, race, age, or sexual identity. The results presented here are based on the experiences of women who contribute and continue to stay in open source communities.

In future research, we would like to continue this work by applying the lens of intersectionality and developing a deeper understanding of differences among the diverse women groups. Ethnicity was not a major distinguishing factor for this data set and did not have much diversity concerning race. All the women interviewed were Caucasian except for one Asian (Indian). The experiences of the only non-Caucasian and non-western woman were very intriguing and will be part of a future study. None of the other women mentioned race as a factor in their experiences.

Conclusion

In this study, we have focused on women who participate in OSS as individuals with specific experiences; some of their experiences are unique, while others exhibit common elements with those of other women or members of other groups, and this nuanced focus has given us an insight into ways in which women navigate OSS communities. We found that OSS communities are complex, and women are motivated to join these communities and support other women in the communities. All the interviewed women face the impact of underrepresentation of women, either in the form of isolation or being put in a position to speak for all women. Our results show that mentors, allies, and leaders in the community have a strong impact on the first experience of women contributors and their continued participation and their continued participation. If they meet the right person(s) in their first encounter with OSS, they continue to participate; when they face challenges and allies and leaders speak up for them, women stay in the communities.

Recruitment and retention of women in OSS are both impacted by the mentors, allies, and leaders. Women who continue to stay in the OSS community face a hostile environment but are committed to contributing and have to develop coping mechanisms in the form of being persistent, stubborn, developing a thick skin, and ignoring negativity. Women are committed to

supporting other women, but communities need to step up compensation that rewards women for mentoring other women. Women do not lack capabilities, skills, or motivation in contributing to the OSS community, and in addition to their time and skills, they also contribute through emotional labor to the success of products.

Endnotes

¹ Please refer to the OSI definition of OSS for a complete reference

(<https://opensource.org/docs/definition.php>)

² GitHub, Inc. is a provider of Internet hosting for software development and version control using Git. It offers the distributed version control and source code management functionality of Git, plus its own features. <https://en.wikipedia.org/wiki/GitHub>

³ Please refer to the Wikipedia definition of “flame war” on Wikipedia [https://en.wikipedia.org/wiki/Flaming_\(Internet\)](https://en.wikipedia.org/wiki/Flaming_(Internet))

⁴ All participant names have been changed to maintain confidentiality.

Appendix A

The Data Collection request was posted on the following women-centered listservs for Open Source Software:

1. Debian Women Mailing List at debian-women@lists.debian.org
2. Fedora Women Mailing List at women@lists.fedoraproject.org
3. Linux Chix Women Mailing List at Announce-request@linuxchix.org
4. OpenSource.Org Women Mailing List at Women-request@opensource.org
5. KDE Women Women Mailing List at kde-women@kde.org
6. Ubuntu Women Mailing List at ubuntu-women@lists.ubuntu.com
7. GNOME Women Mailing List at gnome-women-list@mail.gnome.org
8. INDI-CHIX at Linux Chix indichix@linuxchix.org

The call for participation also asked potential participants to forward the request to anyone they believed could contribute to the research.

Appendix B

Open-Ended Interview Questions

1. Do you recall your first experience of participating in an OSS project? If yes, could you please share that experience.
2. How would you describe your experience of participating in Open Source Software? Please share some specific examples.
3. What motivates you to continue to participate in OSS?
4. In your opinion, are men and women treated equally in the OSS communities you have participated in? Please share some specific examples.
5. In your opinion, is there a difference between the quality of contribution among men and women? Please share some specific examples.
6. What, if any, are the benefits of participating in OSS?
7. What advice would you give to a female who would like to contribute to OSS?
8. How can community members improve the experience of women participating in OSS?
9. Is there anything else on this topic that you would like to share with the interviewer?
10. Is there anything else that you think is important for this topic that is not covered in the questions above?

References

- Adya, M., & Kaiser, K. M. (2005). Early determinants of women in the IT workforce: A model of girls' career choices. *Information Technology & People*, 18(3), 230-259.
<https://doi.org/10.1108/09593840510615860>
- AFP. (2014, October 5). Hajj selfies cause controversy among conservative Muslims. *The Telegraph (U.K.)*.
<http://www.telegraph.co.uk/news/worldnews/middleeast/saudiArabia/11141770/Hajj-selfies-cause-controversy-among-conservative-Muslims.html>
- Agger, B. (2012). *Oversharing: Presentations of self in the Internet age*. Routledge.
- Ahuja, M. K. (2002). Women in the information technology profession: A literature review, synthesis and research agenda. *European Journal of Information Systems*, 11(1), 20-34.
<https://doi.org/10.1057/palgrave.ejis.3000417>

- Amey, K. (2015, July 16). Breathtaking aerial images show millions of Muslim worshippers praying during the night of power at the grand mosque in mecca. *Mail Online*. http://www.dailymail.co.uk/travel/travel_news/article-3164164/Breathtaking-aerial-images-millions-Muslim-worshippers-praying-Night-Power-Grand-Mosque-Mecca.html
- Aneja, A. (2014, October 3). Hajj 2014: The year of the selfie. *Time*. <http://time.com/3462348/hajj-2014-the-year-of-the-selfie/>
- Appadurai, A. (1986). Introduction: Commodities and the politics of value. In A. Appadurai (Ed.), *The social life of things: Commodities in cultural perspective* (pp. 3-63). Cambridge University Press.
- Armstrong, D. J., & Riemenschneider, C. K. (2014). The barriers facing women in the information technology profession: An exploratory investigation of Ahuja's model. *Proceedings of the 52nd ACM conference on computers and people research*, 85-96. <https://doi.org/10.1145/2599990.2600006>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <http://dx.doi.org/10.1191/1478088706qp063oa>
- Chamberlain, A., & Jayaraman, J. (2017) *The pipeline problem: How college majors contribute to the gender pay gap*. Glassdoor. <https://www.glassdoor.com/research/app/uploads/sites/2/2017/04/FULL-STUDY-PDF-Gender-Pay-Gap2FCollege-Major.pdf>
- Ensmenger, N. L. (2012). *The computer boys take over: Computers, programmers, and the politics of technical expertise*. MIT Press.
- Ensmenger, N.L. (2015). "Beards, sandals, and other signs of rugged individualism": Masculine culture within the computing professions. *Osiris*, 30(1), 38-65. <https://doi.org/10.1086/682955>
- Ford, D., Harkins, A. & Parnin, C. (2017). Someone like me: How does peer parity influence participation of women on stack overflow? *IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, 239-243, <https://doi.org/10.1109/VLHCC.2017.8103473>
- Frohard-Dourlent, H., Dobson, S., Clark, B. A., Doull, M., & Saewyc, E. M. (2017). "I would have preferred more options": Accounting for non-binary youth in health research. *Nursing Inquiry*, 24(1). <https://doi.org/10.1111/nin.12150>
- Ghosh, R. A., Glott, R., Krieger, B., & Robles, G. (2002). *Free/libre and open source software: Survey and study (FLOSS), final report, part IV: Survey of developers*. <https://www.semanticscholar.org/paper/Free%2FLibre-and-Open-Source-Software%3A-Survey-and-Ghosh-Glott/76500759b0d46c7fc3bef57c23ffe9f9a14aea14>
- Howcroft, D., & Trauth, E. M. (2008). The implications of a critical agenda in gender and IS research. *Information Systems Journal*, 18(2), 185-202. <https://doi.org/10.1111/j.1365-2575.2008.00294.x>

- Jane, E. A. (2015). Flaming? What flaming? The pitfalls and potentials of researching online hostility. *Ethics and Information Technology*, 17(1), 65-87.
<https://doi.org/10.1007/s10676-015-9362-0>
- Kvasny, L., Trauth, E. M., & Morgan, A. J. (2009). Power relations in IT education and work: The intersectionality of gender, race, and class. *Journal of Information, Communication & Ethics in Society*, 7(2/3), 96-118.
<http://dx.doi.org/10.1108/14779960910955828>
- McGee, K. (2018). The influence of gender, and race/ethnicity on advancement in information technology (IT). *Information and Organization*, 28(1), 1-36.
<https://doi.org/10.1016/j.infoandorg.2017.12.001>
- Mendez, C., Padala, H.S., Steine-Hanson, Z., Hilderbrand, C., Horvath, A., Hill, C., Simpson, L., Patil, N., Sarma, A., & Burnett, M. (2018). Open source barriers to entry, revisited: A sociotechnical perspective. *Proceedings of the 40th International Conference on Software Engineering (ICSE '18)*. Association for Computing Machinery, 1004-1015.
<https://doi.org/10.1145/3180155.3180241>
- Menking, A. & Erickson, I. (2015). The heart work of Wikipedia: Gendered, emotional labor in the world's largest online encyclopedia. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, 207-210.
<https://doi.org/10.1145/2702123.2702514>
- Morrison, S., Fiesler, C., & Bruckman, A. S. (2016). An archive of their own: A case study of feminist HCI and values in design. *34th Annual CHI Conference on Human Factors in Computing Systems*, 2574-2585. <https://caseyfiesler.com/2016/02/09/an-archive-of-their-own-a-case-study-of-feminist-hci-and-values-in-design-chi-2016/>
- Nafus, D. (2012). 'Patches don't have gender': What is not open in open source software. *New Media & Society*, 14(4), 669-683. <https://doi.org/10.1177/1461444811422887>
- NCWIT. (2016). National Council of Women in Information Technology.
https://www.ncwit.org/sites/default/files/resources/btn_03092016_web.pdf
- Nowakowski, A. C., Sumerau, J. E., & Mathers, L. A. (2016). None of the above: Strategies for inclusive teaching with "representative" data. *Teaching Sociology*, 44(2), 96-105.
<https://doi.org/10.1177/0092055X15622669>
- Quesenberry, J. L., & Trauth, E. M. (2012). The (dis)placement of women in the IT workforce: An investigation of individual career values and organisational interventions. *Information Systems Journal*, 22(6), 457-473. <http://dx.doi.org/10.1111/j.1365-2575.2012.00416.x>
- Quesenberry, J. L., Trauth, E. M., Morgan, A. J. (2006). Understanding the "mommy tracks": A framework for analyzing work-family issues in the IT workforce." *Information Resources Management Journal*, 19(2), 37-53. <https://doi.org/10.4018/irmj.2006040103>
- Reagle, J. (2013). "Free as in sexist?" Free culture and the gender gap. *First Monday* 18(1).
<https://firstmonday.org/article/view/4291/3381>

- Robles, G., Reina, L. A., Gonzáles-Barahona, J.M., & Domínguez, S. D. (2016). Women in free/libre/open source software: The situation in the 2010s. *12th IFIP WG 2.13 International Conference*, (p. p. 163-173). Springer International Publishing. https://doi.org/10.1007/978-3-319-39225-7_13
- Rock, D. & Grant, H. (2016, November 4). Why diverse teams are smarter? *Harvard Business Review*. <https://hbr.org/2016/11/why-diverse-teams-are-smarter>
- Shein, E. (2018). Broadening the path for women in STEM. *Communications of the ACM*, 61(8), 19-21. <https://doi.org/10.1145/3231170>
- Singh, V. & Brandon, W. (2019). Open source software community inclusion initiatives to support women participation. In F. Bordeleau, A. Sillitti, P. Meirelles, V. Lenarduzzi (Eds.), *Open source systems* (p. p. 68-79). Springer. https://link.springer.com/chapter/10.1007/978-3-030-20883-7_7
- Singh, V., Bongiovanni, B., & Brandon, W. (2021). Codes of conduct in open source software—for warm and fuzzy feelings or equality in the community? *Software Quality Journal*. <https://doi.org/10.1007/s11219-020-09543-w>
- Steinmacher, I., Conte, T., Gerosa, M. A., & Redmiles, D. (2015, February). Social barriers faced by newcomers placing their first contribution in open source software projects. *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15)*, 1379-1392. <https://doi.org/10.1145/2675133.2675215>
- Tourani, P., Adams, B., & Serebrenik, A. (2017). Code of conduct in open source projects. *IEEE 24TH International Conference on Software Analysis, Evolution, and Reengineering (SANER)*, 24-33. <https://doi.org/10.1109/SANER.2017.7884606>
- Trauth, E. M. (2002). Odd girl out: An individual differences perspective on women in the IT profession. *Information Technology & People*, 15(2), 98-118. <https://doi.org/10.1108/09593840210430552>
- Trauth, E. M. (2006). Theorizing gender and information technology research. In E. M. Trauth (Ed.), *Encyclopedia of gender and information technology* (Vol. 2, pp. 1154-1159). Idea Group.
- Trauth, E. M. (2013). The role of theory in gender and information systems research. *Information and Organization*, 23(4), 277-293. <http://dx.doi.org/10.1016/j.infoandorg.2013.08.003>
- Trauth, E. M., Cain, C. C., Joshi, K. D., Kvasny, L., & Booth, K. M. (2016). The influence of gender-ethnic intersectionality on gender stereotypes about IT skills and knowledge. *The DATABASE for Advances in Information Systems*, 47(3), 9-39. <http://dx.doi.org/10.1145/2980783.2980785>
- Vasilescu, B., Posnett, D., Ray, B., van den Brand, M. G., Serebrenik, A., Devanbu, P., & Filkov, V. (2015). Gender and tenure diversity in GitHub teams. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*, 3789-3798. <https://doi.org/10.1145/2702123.2702549>

Women Who Tech. (2020). *Women Who Tech startup and tech culture survey* [Survey].
https://womenwhotech.com/sites/default/files/2020-09/WomenWhoTech_StartupAndTechSurvey2020.pdf

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