Dismantling Barriers to Participation

How Identity-Based Signals and Mentorship Can Support Engagement in Online Programming Communities

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Abstract. Online programming communities, a type of socio-technical ecosystem, enable a peer support cycle where users can receive technical guidance from other users who encounter similar issues. Yet, there are obstacles that discourage users from participating and gaining help from peers in these communities. This thesis proposes that there are both *social* and *cognitive* barriers, such as receiving offline assistance from an identifiable colleague and overcoming onboarding prerequisites, that exist in *online programming communities*. However, using interventions such as *identity-based signals* and *mentorship*, we can increase engagement in online programming communities. In this thesis, I present a conceptual framework that identifies barriers to participation that can be utilized to increase engagement in online programming communities. The contributions of this proposal are: 1) *a conceptual framework* explaining how programmers are inhibited from participating in online programming communities, 2) *a set experiments and evaluations* that assess how valid and actionable it is to explore and measure participation in online programming communities, and 3) *a proof-of-concept mentorship program* to demonstrate community impact and feasibility of self-sustaining support. My work demonstrates that it is possible to increase engagement of programmers in online programming communities using identity-based signals and mentorship.

My Thesis

Existing mechanisms in online programming communities do not make the contribution process inclusive for novice and underrepresented programmers due to existing **social** and **cognitive** barriers. By incorporating **identity-based signals** and introducing **mentorship**, we can help programmers overcome these barriers and significantly increase participation in online programming communities.

1 Introduction

A Community with Challenges

Online programming communities, such as Stack Overflow and GitHub, are utilized by software developers to share and review code collaboratively. Program-

mers frequent Stack Overflow, a popular question and answer (Q&A) site, to get quick answers to their questions on a range of topics from how to implement a simple sorting algorithm to settling disputes about mobile application security. Likewise, programmers turn to GitHub, a social coding platform to host programmer's code [73], to share open source projects with users from across the globe. Programmers who join online programming communities cite several benefits, including the ability to learn more about programming [48] while contributing to the code of others [77].

However, not everyone participates equally in online programming communities. A survey conducted by Stack Overflow finds that only 7.6% of the site's active contributors identified as women [49], which pales in comparison to the 20% of Stack Overflow that are women [72]. This pattern is not unique to Stack Overflow. A similar survey conducted by Zlotnick and colleagues at GitHub suggest that open source contributors do not yet reflect its broad audience of users [77]. Women and underrepresented groups are virtually absent from online programming communities, even though they comprise about 20% of the software engineering field [33]. For example, David et al. found that women make less than 5% of all open source contributions [10]. There are several theories to explain these low participation rates. Often women do not feel welcomed in these online communities [70] and overall are unfamiliar with community culture and expectations [63,1], hindering their usage. Time constraints associated with these social pressures can limit availability for women to contribute online.

Unequal participation in online programming communities impact the productivity of teams and the health of the software development community as a whole. Increasing diversity in teams correlates with increasing team productivity [73], hence the exclusion of these underrepresented groups from participating can be harmful. For example, on Stack Overflow newcomers are not receiving answers from other users: 90% of accepted answers provided by new users are self-answers [60]. In addition, the community's growth is limited and controlled by a gamified core of elite users: only 5% of the users answer 60% of the questions [52]. However, even gamified mechanics fail to support the sustainability of the community as most users stop doing actions once they earn a badge for doing that action [22].

Thus, my research goal is to understand what barriers are preventing programmers from contributing to online programming communities and find interventions to dismantle them. Identifying the context in which barriers exist can offer guidelines to design interventions that combat challenges users face. In addition, programmers of different experience levels and genders face barriers, such as *reputation-gated permissions* and *being overwhelmed by the large community*, that inhibit them from participating [18]. I hypothesize that dismantling barriers with a variety of approaches, such as guiding novices through onboarding hoops or reducing the feeling of an intimidating community size with a mentor, can help users feel more comfortable participating in online programming communities and other socio-technical ecosystems.

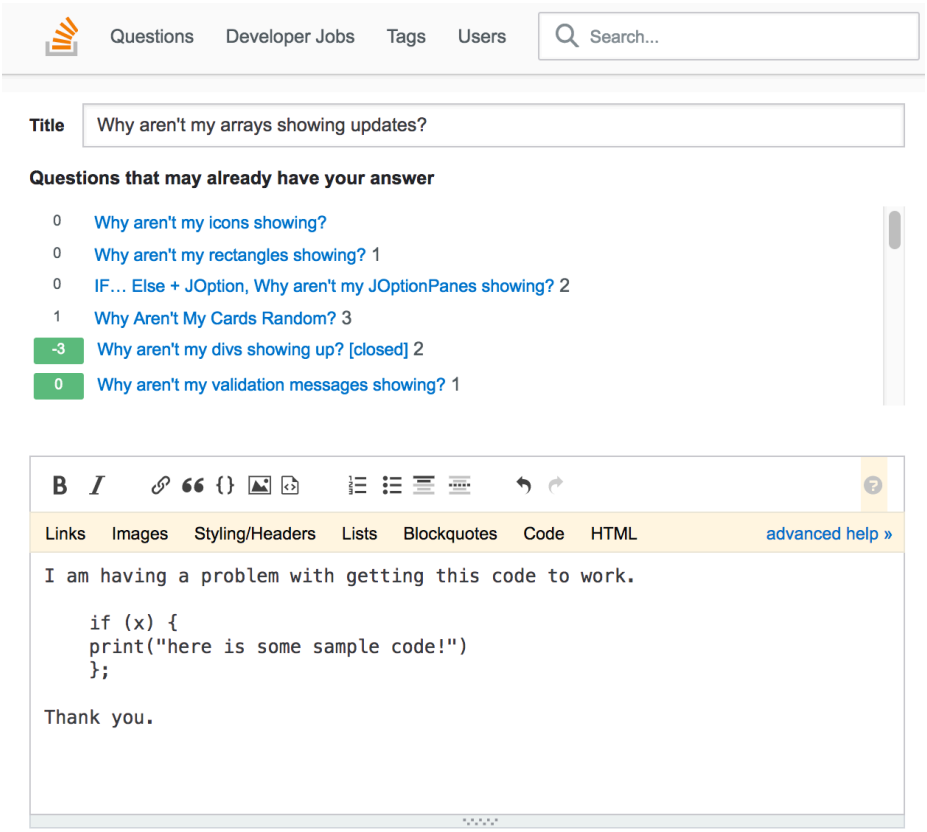


Fig. 1: Writing a question to post on Stack Overflow.

1.1 Motivating Example

To further understand the process of contributing to an online programming community, we will use Asha's experiences. Asha is a programmer who uses Stack Overflow to find solutions to her programming problems, but has never contributed an answer or question before. While programming, she encounters an unfamiliar exception while running her code and searches the internet to find a solution. She selects the first result that shows up: Stack Overflow. Asha briefly scans the page to compare the content of the question posted to the problem she is having. She finds the posted questions to be similar, yet insufficient to solve the complex constraints of her problem. Asha then decides to move forward and post her question on Stack Overflow. She starts to type her question, but for some reason, she hesitates and does not post her question on the site. Perhaps Asha encountered a social barrier and did not post her question online because when reviewing other questions, she did not see other users who look like her post questions. Another likely reason Asha hesitated to post is because she encountered a cognitive barrier of unfamiliarity with community expectations and feels her question is unfitting for Stack Overflow. In addition to the cognitive barriers faced once she musters the interest to post, there are also perceived barriers of how the community operates that can deter Asha's participation. For example, when typing her question Asha is shown a list of dynamically generated questions that may already have her answer, as shown in Figure 1. This may also discourage her from posting a question since it may be a duplicate. Ultimately, these many social and cognitive barriers to contributing online discourage Asha from posting and thus struggles to find a resolution to her problem. The barriers she face can seem insurmountable—inhibiting her and other programmers to ask or provide help in these specialized online communities. In the following sections, I will discuss research that investigates barriers to participation programmers encounter in online programming communities and motivate research a conceptual framework to dismantle them.

1.2 Research Contributions

The expected contributions of this proposal are:

1. *A conceptual framework* for what prevents programmers from participating in online programming communities. This framework outlines social and cognitive barriers (Section 3).
2. *A set experiments and evaluations* that assess how valid and actionable it is to explore and measure participation in online programming communities using identity-based interventions and mentorship to increase participation (Section 5). These experiments demonstrate how to apply the conceptual framework using tools such as eye tracking and signals of identity.
3. *A proof-of-concept mentorship program* to demonstrate community impact and feasibility of self-sustaining support (Section 4). This program indicates that it is feasible and practical to use identity-based interventions in a mentorship program to increase participation.

My work investigates if it is possible to increase programmer participation and the quality of their experience in online programming communities.

2 Background

2.1 What is an Online Programming Community?

An *online programming community*(OPC) is a type of socio-technical ecosystem specific to programming. The term socio-technical ecosystem originates from Trist's description of a socio-technical system where both social and technical communication become essential to professional work [69]. This term has been adapted to "ecosystem" as the sustainability of the community relies on reinforcement of consistent social and technical dialogue from members. What makes these communities an ecosystem is the many types of members, how their actions can effect each other, and how they develop niches [27]. These factors also present four fundamental problems of socio-technical ecosystems: architecture, business opportunities, coordination, and governance [27]. In this work we tackle the issues of architecture and governance to increase participation in online programming communities.

There are several mechanics of online programming communities, such as Stack Overflow and GitHub, that make them unique. One is how users engage through the action of asking questions and receiving answers. Stack Overflow reflects this through curating questions and answers as the primary interaction. Similarly, GitHub reflects this with collaborative contributions to open source project through pull requests and issue reports. In short, this serves as a core interaction within these communities. Community members, often without restrictions, can contribute these types of content at any stage in their tenure on the site. Another is the feature of voting to help moderate content. Upvoting and downvoting content allows for both questions and answers to have scores. In addition to the aforementioned facets of the ecosystem, community members can also have reputation points. Reputation points can demonstrate a member's tenure on the site, their level of activity, and what facets of the community are they most active in.

In addition to features that provide the foundation for online programming communities, there are alternative ways to reinforce content management of these communities. For example on GitHub, project maintainers, selected by the project owner, can accept and decline pull request for code changes. Similarly on Stack Overflow, moderators, elected by a community vote, serve as community safety patrol with rights to close questions, lock posts from further edits, and even conduct long term maintenance of the site[1]. While project maintainers and moderators are afforded rights to manage content, new users have a limited scope of contributions. In this work, I study this range of participation in online programming communities.

[1] `https://stackoverflow.com/help/site-moderators`

2.2 Theory from a Community of Practice

A *community of practice*(CoP) is defined by "groups of people informally bound together by shared expertise and passion for a joint enterprise [35]." The term is used broadly to include communities ranging from professional networks on email lists to offline technical support forums. Online programming communities, such as Stack Overflow and GitHub fit well within the community of practice framework. Stack Overflow can be understood as a community of developers bound together by shared expertise and passion for programming. One mechanism for improving participation in a community of practice is *legitimate peripheral participation*, a model that describes how newcomers can become members of a community of practice. For example, a user can initially participate in "peripheral yet productive tasks that contribute to the overall goal of the community," i.e., correcting small errors on a Wikipedia page. Newcomers gradually learn about tools, tasks, vocabulary, and organizing principles of a community (such as abbreviations or discouraged behaviors). Finally, newcomers can be exposed to expert practices and understand the context of both their actions and expert actions by working together, e.g., *mutual engagement* [74]. In this work, I study how mutual engagement can influence newcomer participation in online programming communities as a community of practice.

2.3 Social Facilitation

Through the co-action effects of social facilitation, programmers can influence others to participate in online programming communities. Triplett first describes social facilitation through competition experiments and studies factors that can influence performance as a difference in performance with and without peers [68]. Co-action effect expands this demonstrating that peers executing the same task resulted in an increased performance. Zajonc identified co-action effects that the actor's response to an audience depends on both how they learned the action they perform with co-actors and the complexity of the task [76]. Hunt and Hillery found a significant difference in performance among women performing a complex task with other women as actors [30]. However, the aforementioned studies are not conducted in online socio-technical settings with the influence of an audience of a similar identity. In this work, I study co-action effect through the complex task of describing a programming problem with those of a similar identity.

2.4 E-mentoring

E-mentoring can encourage programmers feel more comfortable and as a result participate more online. Bierema and colleagues define e-mentoring as "a computer mediated, mutually beneficial relationship between a mentor and a protege which provides learning, advising, encouraging, promoting, and modeling, that is often boundaryless, egalitarian, and qualitatively different than traditional face-to-face mentoring [6]." In socio-technical ecosystems, e-mentoring can impact

participants by enhancing technical skills and forming interpersonal relationships [67]. In this work, I study the effects of introducing e-mentoring in an online programming community.

2.5 Problems with Inclusion

There is a lack of inclusion in online programming communities. Borrowing from Roberson's interpretation, I will refer to inclusion as a representation of a person's ability to contribute fully and effectively to a community [55]. Of course, systemic factors already in effect can deter a fully inclusive community, but I believe progress towards that goal can be measured through empirical studies. Inclusion can be measured based on concepts from the confirmatory factor analysis as relevant to online programming communities such as, equal access to opportunities and a communities flexibility to users [55]. In terms of online programming communities, the lack of inclusive participation in the community has encouraged characterizations with many approaches [37,72,49]. However, studies reach a similar conclusion: underrepresented users are discouraged to participate on Stack Overflow and GitHub. In an effort to explain why, research demonstrates there is not an inclusive group of programmers participation in online programming communities [71] and identify barriers as to why it may be so hard for underrepresented groups to contribute [18]. This presents an opportunity to explore these challenges and devise approaches to facilitate a more inclusive online programming community.

2.6 Research Overview

Taking the aforementioned into account, my research will study approaches to increase participation for novices and underrepresented groups and create a more inclusive online programming community. To understand interactions of online programming communities, I identify barriers and propose two interventions to increase how programmers participate online: 1) identity-based signals and 2) mentorship. The following section outline barriers to participation, how identity can be used as a signal to encourage participation, and how mentorship can support engagement.

3 Empirical Investigation of Barriers and Identity

I propose a conceptual framework to identify how programmers face barriers when contributing to online programming communities. Designing a framework presents researchers with a taxonomy of defined problems in order to derive targeted solutions. In the following sections, I describe our empirical investigation of barriers and identity. Additional details on the creation of these barriers can be found in Appendix A. This work is published in FSE '16 [18].

Study Rationale. To create this framework, we conducted a study where we interviewed and surveyed programmers about their participation on Stack Overflow. We focused on Stack Overflow in order to understand barriers to participation in an online programming community because 1) the content is accessible to users at a range of experience levels thus providing no interaction constraints on the number of participants, 2) the content is less project specific thus allowing for more partitioned experiences from each participant, and 3) the disparities in participation on Stack Overflow are acknowledged in prior work, but not yet explained. We sought to understand the relationship between barriers through factors such as gender, participation level, and professional development experience.

Methodology. To discover what barriers Stack Overflow users encounter, we use a mixed-methods approach. We conducted semi-structured interviews with 22 women developers in order to understand what prevents them from actively participating on the site. Our focus was on women because we wanted to understand the obstacles they face and identify possible solutions. We interviewed women developers from a wide range of experience and levels of using Stack Overflow (from lurkers to a top 100 user). From these interviews, we identified 14 barriers based on common experiences of participants. To validate and understand how these barriers might differently affect both women and men users, we sent a survey to software developers, receiving responses from 134 women and 1336 men. From the survey, we identified which barriers women and men face and which ones are gender-specific.

3.1 Barriers Identified

We identified 14 barriers to contributing in online programming communities. For the purpose of this work, we defined a *barrier* as, *an obstacle deterring user participation.* The barriers in the framework are categorized into three groups based on how programmers described their challenges contributing. In the descriptions of these barriers we refer to *social barriers* as obstacles that limit the social interactions users seek and *cognitive barriers* as obstacles that lead to cognitive burdens users with endeavors to engage in the community encounter. *Muddy Lens Perspective* describes how particular perceptions and expectations (whether justified or not) acted as barriers to contribution. *Impersonal Interactions* describes how the lack of personal interactions became a social barrier for their usage. *On-Ramp Roadblocks* refer to cognitive barriers encountered that undermine interest in contributing.

The following barrier descriptions have been paraphrased from the perspective of a programmer for clarity purposes. Each barrier is labeled with the number and first letter for the group it belongs to. For example, the *awareness of site features* barrier is in the Muddy Lens Perspective group and is labeled `M1`.

Muddy Lens Perspective

`M1` Awareness of site features—I feel I am simply unaware of and have not explored features.

M2 Nothing left to answer—I feel all the easy questions have already been answered, leaving only hard questions.

M3 Fear of contributing to clutter—I feel my question might just be a duplicate or unimportant question, so I refrain from posting.

M4 No "good-answer" guarantee—When posting a question, I fear not getting a good answer.

M5 Perception of slacking—I feel that I should not be spending time answering questions on Stack Overflow for my own personal benefit.

Impersonal Interactions

I1 Fear of negative feedback—I fear my posts being harshly criticized.

I2 Stranger discomfort—I feel uncomfortable interacting with and relying on help from strangers online.

I3 Intimidating community size—I feel intimidated by the large community of users. I instead prefer connecting with a smaller and more intimate group.

I4 Posting is hard, friends are easy—I feel the process of posting questions is too cumbersome compared to other resources such as asking friends for help.

On-Ramp Roadblocks

O1 Abstraction process—I feel my problems require too many dependencies or proprietary aspects for me to abstract away before having something I can ask to a general audience.

O2 Time constraints—I feel making contributions on Stack Overflow requires more time than I have.

O3 Qualification—I feel my expertise or answers would not be of any help to anyone else.

O4 On-boarding hoops—I feel figuring out the unspoken social etiquette and community standards is too much work.

O5 Research pressure—I feel discouraged by the amount of work I have to do to prove that I am not asking a duplicated question.

3.2 Identity-Based Participation

To find how identity can dismantle barriers to participation online, we conducted a qualitative study on the perceptions of the #ILookLikeAnEngineer identity hashtag movement [38]. To counteract engineering stereotypes, the movement called for engineers to post selfies with the hashtag on social media sites [65]. We chose to study this hashtag because of its focus on a specific stereotype, whereas many other identity hashtags (e.g., race- or gender-specific) tend to address communities that revolve around much broader issues. The professional nature of the hashtag also allowed us to explore issues in intersecting professional identities with online social movements, where challenges may arise in maintaining a professional online persona when posting about a controversial topic. Understanding identity-based hashtag movements revealed strategies to improve STEM diversity in socio-technical ecosystems such as identifying a collective a user may belong to and the impacts of identifying that collective.

4 From Barriers to Bridges: Applying the Conceptual Framework

Each barrier can be used as an outline to develop interventions that increase participation in online programming communities. Next, I explain how we can use barriers to form bridges that increase participation through identity-based signals and a community mentorship program. For my thesis, I have selected a subset of both social and cognitive barriers to demonstrate how this framework can be applied.

4.1 Using Identity-Based Signals to Increase Participation

One barrier that we can target to increase participation is *Posting is Hard, Friends are Easy*. Prior work indicates that users in online communities seek peers and individual users they can identify with on the site to be a challenge [18]. In addition, social facilitation theory demonstrates identifying companions in a community can increase the likelihood of participation. Thus, giving users access to identity-based signals can increase their engagement and participation.

To use identity-based signals to increase participation, we must determine and characterize the different types of identities that are available and how they are used online. Examples of identities that can exist in online programming communities include user names, full names, profile images, location, educational status, accessibility requirements, employment status, gender, ethnic group, and more. Prior work on identity-based participation in online socio-technical ecosystems demonstrate that posts with photos received more activity than those without [38]. Although external identity sharing further influenced participation, implicit identity sharing also encouraged a more inclusive community for participants and lurkers. Given the ability to access many forms of identity, the next step is to assess the use and influence of these identities for programmer engagement in online communities.

4.2 Using Community Mentorship to Increase Participation

Another barrier we can focus on to increase participation is *Fear of Negative Feedback* and *Onboarding Hoops*. With a mentorship program we can reduce the onboarding hoops of novice users acclimating to the community through the guidance of more experienced users. I use the following principles to guide this community mentorship program:

Provide formative and timely feedback. Existing community mechanisms help curate content, but limit the quality of feedback askers receive. First, comment conversations are slow, often taking hours or days, which reduces the effectiveness of the feedback [11]. Second, questions can be modified without the knowledge of the asker, which limit the learning opportunity for the asker to directly improve the question themselves. In designing a synchronous style of communication, we can increase the promptness and effectiveness of the feedback given.

Allow mistakes in a private space. Many new users are likely to make mistakes that will result in public negative criticism [12] or unanswered questions. As a result, their already low reputation is harmed by downvotes on their initial questions and they are more likely to disengage from the community [18]. In designing a private setting, users can make mistakes and feel comfortable learning from them.

Do not solve problem, give feedback for better contributions. How mentors advise is pivotal to increasing learning gains and engagement. In designing a system for experienced users to provide devoted feedback on a question, without competing with the community-at-large, mentors can guide novice users to improve their contributions to the community. By working together on improving a contribution, new users and mentors participate in *mutual engagement* [74], an effective method for onboarding new participants in a community of practice.

In the above sections, I have outlined the significance and conceptual framework behind my proposed research. Next, I will outline the experiments and evaluations I will complete for my dissertation.

5 Experiments and Evaluations

In this section, I describe completed and future studies to complete this thesis. The current status of each experiment, and the completed or proposed semester of completion, is indicated in parentheses. The brackets in each section header indicate a short name for the experiment.

5.1 `[Peer Parity]` How does identifying peers in a community encourage users to participate? (Completed, Fall 2017)

Study rationale. Several studies have identified reasons for low participation rates in underrepresented groups, but few have identified how identity can play a role. In a recent study on Stack Overflow participation among women, subjects mentioned that one reason they do not post on Stack Overflow is that *"They are just not even on the same race track [18]."* I define this notion of observing people on the same "race track" or having similar individuals to compare oneself to as *peer parity*. Peer parity is when an individual can identify with at least one other peer when interacting in a community. Research external to programming communities suggest the presence of peers can increase activity from underrepresented users in unfamiliar spaces. Does the same hold true in online programming communities? Building on studies of identity and peer interactions [64,20], I hypothesize that differences in exposure of peer parity may influence participation in online programming communities.

Research question. To investigate this hypothesis we focus on the online programming community of Stack Overflow and ask the following question:

`RQ` How does peer parity influence how women post on Stack Overflow?

Methodology. *Data collection.* We extracted 5,987,284 users and 32,209,817 posts from the Stack Overflow Data Exchange. The oldest post of the data we studied is July 31, 2008 and the latest is September 4, 2016. After we gathered all threads we identified genders of the users based on their display name with Vasilescu et al. genderComputer Tool [72]. The reported precision of genderComputer is about 90%. We modified the tool to review the first name of a user and determine where a variation of that name exist in a list of names with a gender across any country. This results in our tool having higher precision in determining genders. The tool reports the gender of the user as male, female, unisex, or undetermined. In our work, we report females as women and males as men. With our modified tool, we computed the gender of 5,987,284 users and identified 363,133 women; 2,139,305 men; 102,189 unisex; and 3,382,657 undetermined names. More details on the modified gender computing tool are available online [24].

Approach. For our research question, we determined that peer parity exists if there is more than one distinct woman on a thread. We refer to this as *parity*. Otherwise, we describe threads that only have one distinct woman as *non-parity*. To clarify, we do not specifically isolate posts with only women. From our extracted data set we identified 32% of all identifiable women who have ever posted a question. First, we randomly selected 1000 women who have ever posted more than one question. Second, we gathered their first question and their second posted activity. Third, we identified the time difference between activity. We selected women who have asked questions to control for a shared first experience on the site.

Analysis. We calculated the gender of all users on a thread and identified whether their first question was on a parity or non-parity thread. We used the time difference between their first question and second activity as a comparison of how soon they re-engage in the community. We also identified the reputation points and number of badges for each of the women. We used the number of reputation points, which are a measure for how much the community trust users, as a measurement for frequency of activity [51]. The number of badges is one way Stack Overflow demonstrates positive user activity [50]. Both the number of badges and reputation points are also visibly adjacent to the user name of a question or answer.

Results. The results from this study are published in VL/HCC '17 [16]. Of our 1000 randomly selected women, we identified 452 parity and 548 non-parity threads from their first question. We found a significant difference in type of second activity after participating on a parity or non-parity thread ($p = 2.799\text{e-}06$, $\alpha = .05$), which was either posting a question($N = 833$) or posting an answer($N = 167$). We found a significant difference in the time between posts for women who asked a question on parity threads in comparison to non-parity threads ($p = 1.83\text{e-}05$, $\alpha = .05$). The cumulative time differences by posts are demonstrated in Figure 2. This figure demonstrates that the longest time difference for a parity activity was 1017 days and 1347 days for a non-parity activity.

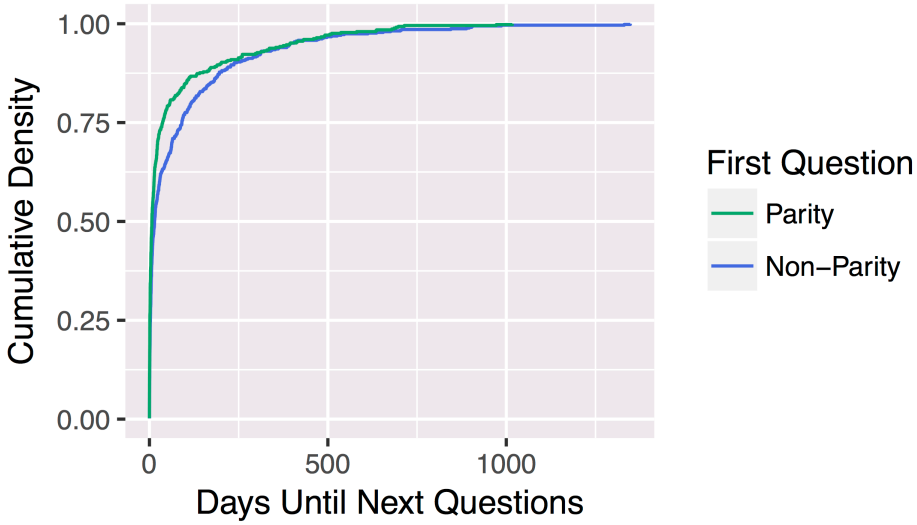


Fig. 2: The time between activity for parity and non-parity threads. The x axis indicates a time difference in days until their next activity after either posting a question on a parity or non-parity thread. The y axis indicates the cumulative frequency of within that time frame. This graph demonstrates that women participating on parity thread have post more immediately after participating on non-parity thread.

We did not find a significant difference in reputation points or number of badges. We observed a small effect size among the comparison of time differences($d = .1$), reputation($d = .1$), and number of badges($d = .2$).

These results demonstrate that women who ask questions on parity threads engage sooner in Stack Overflow participation activities. Thus, supporting my thesis that identity-based signals, in this case gender, can increase participation in online programming communities.

5.2 `[Community E-Mentorship Program]` How do new and experienced users benefit from participating in an online mentorship program? (In progress, Spring 2018)

Study rationale. On Stack Overflow, many questions from novices are ill-received: downvoted, left unanswered, or deleted [3]. In addition, programmers of different experience levels and genders face barriers—*reputation-gated permissions* and *being overwhelmed by the large community*—that inhibit them from asking questions [18]. Actualizing design claims of online communities [32], I propose that dismantling barriers with varying approaches, such as guiding novices through onboarding hoops or reducing the feeling of an intimidating community size with a mentor, can help users feel more comfortable participating in online

Fig. 3: An example of how novices will be greeted by mentor in Stack Overflow Mentorship Room.

programming communities. For this study, I focus on Stack Overflow because of its transparency as it relates to the quality of the user experience [49].

Research questions.

RQ1	How do novices and mentors benefit from peer mentorship?
RQ2	How do we make human-human peer mentorship sustainable?
RQ3	What are the long term effects of participation in a mentorship program?

Proposed methodology. *Approach.* To study collaboration styles between mentor and novice, I will create a forum called a *help room*, a system similar to the existing Stack Overflow Chat system[2]. In this help room, novices will post their draft question and a mentor knowledgeable of the question will be able to help. As novices and mentors enter the help room, the system will inform both that this forum is not for answering Stack Overflow questions, but for help on how to get acclimated to the site.

Data collection. Data collected will be based on the interactions between novices and mentors in this new collaborative help room and recorded in transcripts. To obtain novices for this program, I will first identify Stack Overflow users who are writing a question to be posted on the site and have below 15 reputation points and have asked less than 3 questions. On Stack Overflow 15 reputation is a key threshold for several on-site privileges and can indicate users

[2] https://chat.stackoverflow.com/

that are still getting acclimated to the community. Once novices are prepared to post their question, I will present the option to receive help from a mentor. When the novice selects to receive help from a mentor they will enter a room where they will be greeted by a mentor, as shown in Figure 3. To obtain mentors, I will post a mentor questionnaire for high reputation users and leaders to participate. Identifying high reputation users and leaders in the community will help refine the best group of mentors to help novices as questions.

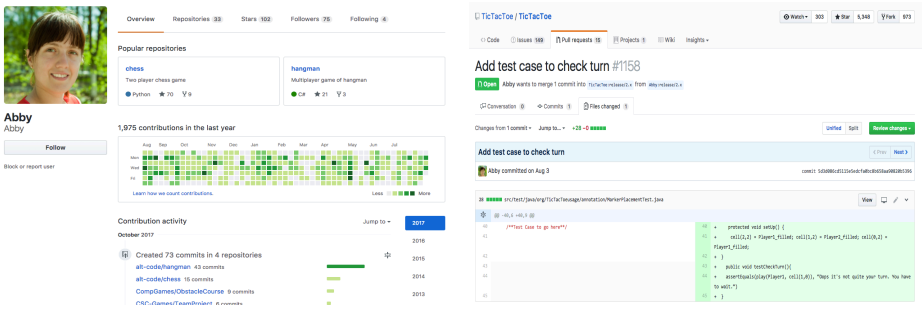
Analysis. For RQ1, I will perform a qualitative analysis on help room transcripts and review interactions between novices and mentors for emergent themes of of help novices receive. I will also conduct statistical analysis to identify differences between the scores and re-engagement rate of users who participated in the mentorship program. For RQ2, I will study how mentors suggest improvements to questions and how novices respond in order to determine what can be adopted by an automated mentor. For RQ3, I will conduct follow-up interviews and administer surveys to measure the long term effects of participating in the mentorship program.

Expected outcomes. I expect both novices and mentors to have a revived outlook on how to participate through posting questions on Stack Overflow. I also expect novices to be more likely to post questions than those who did not participate in the help room. I expect mentors to have an increased awareness of how new users get acclimated to the community and thus encouraged to aid new users even outside of participating in the mentorship help room. I expect the mentorship help room to change the way people use Stack Overflow by providing a space where mentors and novices can improve the quality of questions posted by new users.

5.3 `[Contribution Signals]` What signals of participation do programmers use to evaluate code contributions? (Proposed, Summer 2018)

Study rationale. Online programming community users often have to make decisions to accept or decline the code contributions of people they do not know [40]. As evaluations of code contributions transition to incorporate more transparency of identity [9], there are more identity-based attributes that are taken into consideration. Although we know users seek out individuals whom they resemble [16], it is unclear what signals of identity users exploit to find common identities and how that effects participation. I plan to identify which signals of identity programmers consume when deciding whether to participate in an online programming community. To determine what signals programmers consider, I plan to conduct this study on GitHub pull requests (Figure 4) and Stack Overflow threads (Figure 5). For example, Figure 5 demonstrates example signals of identity that users may fixate on when making the decision to post an answer to a Stack Overflow thread.

These signals include but are not limited to:



((a)) GitHub profile ((b)) GitHub pull request

Fig. 4: This diagram demonstrates signals of a GitHub profile and pull request.

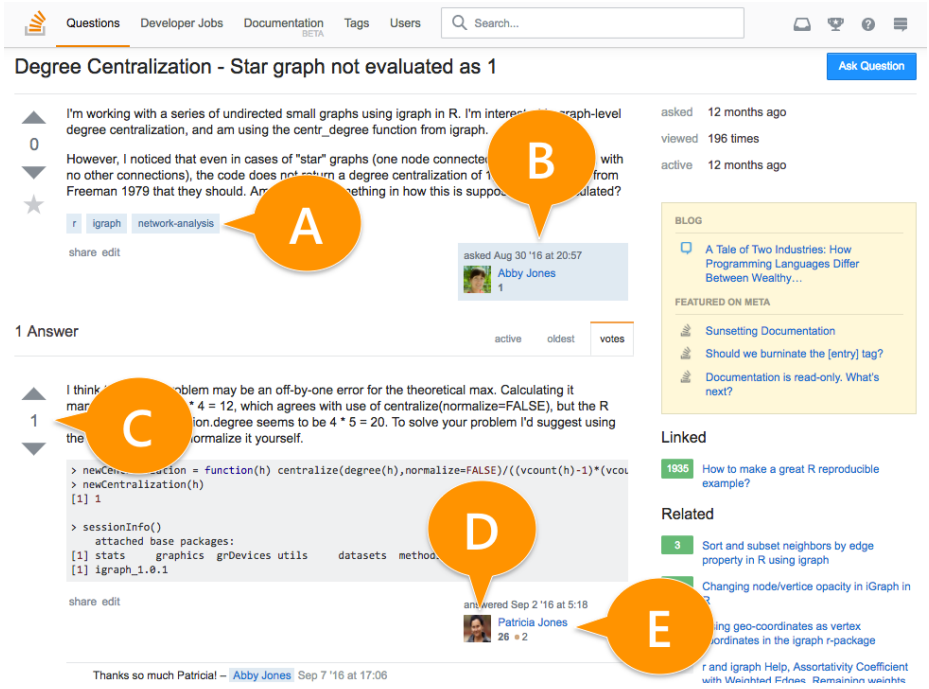


Fig. 5: This diagram demonstrates signals of a Stack Overflow thread that users may fixate upon in order to participate.

A tag describing the topic of the question
B profile description of the user who asks the question
C score of a question or answer
D display image of the users who answer
E display name of the users who answer

Research questions.

RQ1	Which signals do programmers use to decide to participate in a community?
RQ2	How can variations in these signals further influence engagement?

Proposed methodology. *Data collection.* To understand how programmers decide to contribute to an online programming community, I will conduct an experiment using eye tracking glasses to collect their approach of reviewing code contributions. I will recruit participants for this study through convenience sampling as the eye tracking glasses require the experiment to be limited in location and those who do not require corrective eye wear to view a computer screen.

Approach. First, the participant will take a pre-test that will assess their familiarity with contributing to online programming communities and how the frequency of contributions. Second, I will don each participant with an eye tracking device, calibrate, and brief them on the protocol of the experiment. Their perspective and opinions will remain anonymous. This will allow participants to be more forthright with their opinions when describing why they would contribute to the displayed thread. Then I will show each participant a series of mock-ups reflecting code contributions that include the signals listed above. I will then ask participants if they would be interested in posting on this thread and why. Next, I will administer an participants an implicit association assessment to understand signals employed[3]. Following the implicit association assessment, I will administer a follow-up semi-structured interview with participants to compare which signals of identity they said they used and what signals their eyes fixated on during the experiment. After the interview, I will debrief participants and ensure they know that all contributions are mock-ups and that their identities will remain anonymous when sharing the data from this experiment.

Analysis. For RQ1, I will analyze the fixation and scan paths when reviewing code contributions. For RQ2, I will analyze differences in a participant's procedure when they review contributions with a variation of identity signals, such as profile image and user name.

Expected outcomes. From this experiment, I expect to find a difference between what signals participants fixate on when determining if they would be interested in posting on a thread. I expect participants to have a longer fixation duration on the display image and name of the top answers than the content, including code snippet, of the answer. I expect to find that participants who have a similar identity characteristic as the code contribution to demonstrate a significant difference in fixation duration than participants who do not. One example of this may be demonstrated in participants who are women reviewing code contributions of identifiable women. I also expect to find a mismatch as to what participants may fixate on in comparison to their interview responses.

[3] `https://implicit.harvard.edu`

Many participants may perceive reviewing technical contributions as a meritocracy, however there may be other implicit signals in effect.

5.4 [Career Signals] How do online programming communities with identity-based job opportunities encourage users to participate? (Proposed, Fall 2018)

Study rationale. One motivation for active users to engage in online programming community is to increase their visibility for career opportunities [48]. However, there is often a mismatch between how interviewers and candidates interpret each other [15]. This may even happen before candidates get to the interview if the jobs available to them misalign with their identity. If jobs are one reason users contribute to online programming communities, how does that influence users of underrepresented backgrounds to contribute? Do the same attributes of posting questions and answers to Stack Overflow of badges, tags, and job perquisites influence interest in job listings? For this study, I propose using Stack Overflow Jobs[4] as GitHub does not have the same structure of job postings across multiple organizations. I hypothesize signals that may significantly increase inclusion of more candidates include, but are not limited to:

F salary range
G visa sponsorship
H relocation services

Research questions.

RQ1	What signals are candidates using to identify applicable job postings?
RQ2	How do online programming communities with job opportunities encourage inclusion for more users to participate?
RQ3	How do signals used to apply for job descriptions vary from signals used in posting in online programming community?

Proposed methodology. *Data collection.* To investigate signals candidates use to identify applicable job postings, I will conduct an eye tracking experiment as candidates evaluate postings and further review job descriptions.

Approach. First, the participant will take a pre-test that will assess their approaches for applying for jobs online. Second, I will don each participant with an eye tracking device, calibrate, and brief them on the protocol of the experiment. Their perspective and opinions will remain anonymous. Again, this will allow participants to be more forthright with their opinions when applying for jobs. Then I will show each participant a list of job ads reflecting their interest as

[4] https://stackoverflow.com/jobs

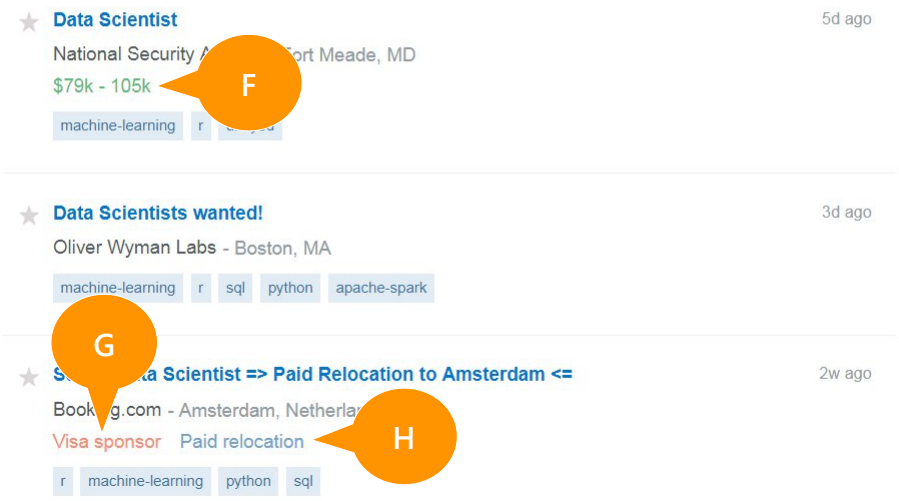


Fig. 6: Signals from Stack Overflow Career Job Postings

shown in Figure 6. I will then ask participants if they would be interested in posting on this thread and why. I will then administer a follow-up semi-structured interview with participants to recall what signals of identity they use to review job postings and what signals their eyes fixated on during the experiment. After the interview, I will debrief participants and ensure they know that all contributions are mock-ups and that their identities will remain anonymous when sharing the data from this experiment.

Analysis. For RQ1 and RQ2, I will analyze eye tracking data from users to identify fixation and areas of interest to compare signals used. For RQ3, I will compare and contrast these findings to that of the `Contribution Signals` Study (Section 5.3).

Expected outcomes. I expect to find that programmers of underrepresented groups to be more likely to apply to job postings that are more transparent about what they can offer candidates. I also expect to find a mismatch between what candidates are seeking in recruiters and what job recruiters are seeking from candidates. As candidates may be familiar with engaging in an online community in a particular way, I expect to find that candidates will employ similar signals as found in `Contribution Signals` to identify job postings.

6 Related Work

My work is guided by research related to posting online as a part of an identity, finding others that share that identity, and how both may encourage posting on programming questions online.

6.1 Nature of Sharing Identity Online

Sharing an identity online has advantages for different communities. Some people share their real name online as a way to gain social capital in virtual communities [62]. Sarma et al. demonstrated the utility for programmers to share their profiles online in order to increase their visibility and showcase their talents for future careers [59]. In addition, Archdivelli et al. found many cultural differences in sharing identity online across many countries within the same context [2]. Building on this, we study identity through the cultural context of gender and how it may influence programmer contributions online.

Posting questions online can mean users must make themselves vulnerable and admit their knowledge deficit in a public sphere. This can be discouraging to many because they may want to remain anonymous, may be shy about posting, or decide that it may be the wrong group for them to participate in [44]. However, what can encourage users to post online and use their identity is knowing that they are not the only person being vulnerable [61]. In this work we hypothesize that some women may seek a community of peers that they can identify with.

6.2 Barriers to Online Contribution

Research identifies multiple barriers for contributing to online communities. Online communities, such as open source projects, are prone to conflict [13], which can be discouraging to users. For new users in an open source programming community, Steinmacher et al. [63] identified social barriers such as documentation issues, technical hurdles, and cultural differences that can hold newcomers back. Ridings et al. found that psychological barriers such as trust in the community can restrict contributions to online as well [54]. In examining barriers in online knowledge sharing, Hew at al. found that a lack of time and comfort with expertise are major obstacles to contribution [28]. Consequently, Kraut et al. describe pivotal design claims that address both time and comfort through prompt feedback and a connecting to a bespoke subgroup which can help retain users in online communities [32].

Though these barriers can restrict online activity for some, not all forms of activity are impeded by them. Vasilescu et al. found that males participate longer than women in Stack Overflow activity [71]. Though women posted more questions, both genders received the same amount of answers [72]. The relatively "unhealthy" [72] community that is generated from this activity causes women to disengage sooner than males. In our work, we dive deeper into the online contribution experience to explain why this disengagement occurs.

6.3 Lurkers and Non-Adopters

Researchers have studied low participation in online communities outside of the technology field [5,21,41]. For example, Lampe et al. studied non-adopters of Facebook and found a divide that emerged between light users and heavy users of the community [34]. A common category of light user, colloquially referred

to as a lurker, is one who is able to witness the interactions of community but is overall not engaged with a community. Lurkers exist in many types of communities, such as discussion lists [46], file-sharing tools [42], and bulletin board systems [66,53].

According to Nonnecke et al. [45] people in communities lurk because: (1) there may be a mismatch between expectations from the community and the lurker, (2) lurkers are learning and getting familiar with the community without interjecting, and (3) lurkers already feel like they are members of the community and don't see a value in increasing their presence amongst other contributors. We investigate many of these factors of lurking in our work.

6.4 Diverse Peer Influence

Ichinco et al. identified that community members who become leaders can influence how other users identify with a community [31]. Identifiable leaders can also be helpful as peers now have a personal example of how to approach a similar goal as the leader. One example of this encouragement is through higher education among underrepresented groups. Gershenson et al. found that when Black students who received access to teachers that resembled them, those students were more likely to go to college and seek similar career paths as their teachers [20]. In addition to race, we see similar effects in gender spheres. When people can see women in nontraditional positions, more than just women are likely to aspire for those same roles [7,19]. In summary, access to a diverse range of examples and role models makes a difference.

Identifying peers can heavily influence how people respond in programming communities, especially among women. Teams consisting of more women are found to be more successful and productive [73]. Intergroup relation theorists have identified that there is a strong cognitive preference for women among women in terms of identity [58]. Ford outlined an application of the Bechdel Test to determine how presence can effect a women on Stack Overflow [14]. In our work, we demonstrate that an in-group preference among women may exist in online programming communities and how recognizing this exist.

6.5 Women Who Code

We study women who code as they are one of many underrepresented groups in computing [8,56]. With this strong push for programmers who are women, there are many resources to encourage their retention in computing and have them feel more confident in their abilities. Cuny and Aspray have outlined a list of recommendations as to how keep women in computing including mentorship and broadening institutional culture [8]. Having these recruitment and retention techniques is one way to increase the visibility of women. Another is having resources women feel comfortable using as they deem necessary [36]. In an effort to relate these disparities, there is research to support the experiences of women in classroom [23,25] and corporate settings [4]. However, these do not prescribe solutions for online community-based resources.

Persistent problems continue to exist. Margolis and Fisher found that a persistent perception of a geek mythology culture in technology discourages women more than men and promotes expectations of male success and continual questioning of woman's abilities [39]. Women start at a disadvantage to their male peers: women who code are nearly twice as likely to have less than 2 years programming experience than their male counterparts [47]. Although their years of experience is low, this value can be interpreted as a small gain for more interest of women in programming. Encouraging the few women in software engineering we have is important to get them in position to be role models for someone else [8]. Following the example of the aforementioned studies, we propose designs for women to participate more in these communities and take advantage of their piece of "programmer's paradise" [26].

7 Project Plan

Figure 7 indicates a monthly plan for each project project proposed in this thesis document. I refer to projects in the figure using short names described above (Section 5). This figure does not include completed and published projects.

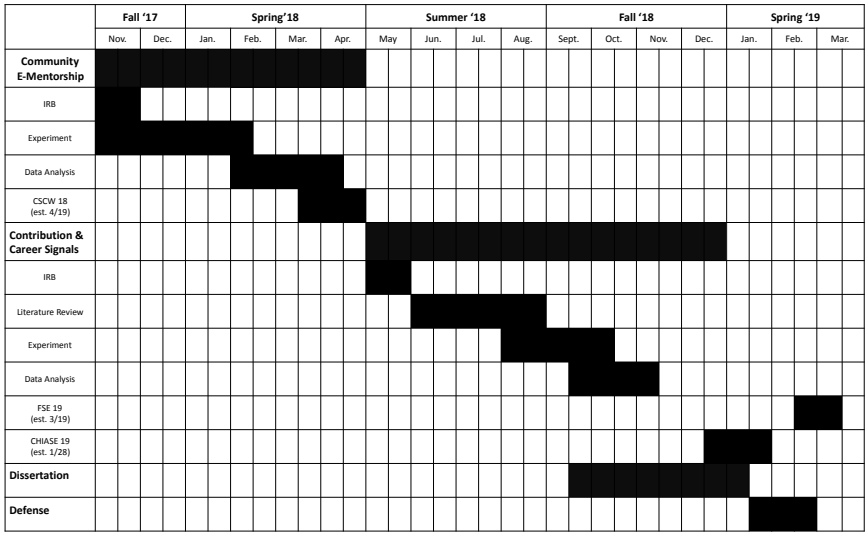


Fig. 7: Monthly project plan to complete dissertation.

7.1 Completed and Published Projects

I have published findings on `Stack Overflow Barriers` to FSE 2016 and `Peer Parity` to VL/HCC 2017.

7.2 Upcoming Projects and Publications

I have begun conducting pilot experiments for the mentorship program. In the Spring of 2018, I will conduct the experiment an data analysis. I plan to submit findings from `Community E-Mentorship Program` to CSCW in April of 2018.

In the Summer of 2018, I plan to work on the `Contribution Signals` project and further literature review of identity deployment. I plan to submit preliminary findings from that work to FSE in March of 2019.

In the Fall of 2018, I plan to work on the `Career Signals` project. I plan to submit the preliminary findings of the work to CHASE in January of 2019 and supplementary findings will be submitted to FSE in March of 2019.

In the Spring of 2019, I plan to compile my dissertation and defend this thesis.

8 Thesis Contract

I will provide the committee with the following deliverables upon completion of the dissertation:

- ☐ Dissertation chapter on `Community E-Mentorship Program`
- ☐ Dissertation chapter on `Contribution Signals`
- ☐ Dissertation chapter on `Career Signals`

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Appendix

A Extended Investigation of Barriers

The following describes the details of the Empirical Investigation of Barriers.

Interviews As the objective of this work is to find out what females consider as barriers to participating on Stack Overflow, it makes sense to start by asking females (and not males) about their experiences. We interviewed female developers to understand how they use Stack Overflow. We recruited female developers from a variety of usage levels (no accounts, occasional contributor, and active contributor) and experience levels (students and professionals). In addition, we recruited one of the top ranked active female users. Identifying a female user who is ranked as a top user presents the opportunity to find out what encourages her to use the site and identify strategies to overcome barriers. In interviewing this

Table 1: Interview participant demographics. A * denotes the highly ranked user.

Participant	Occupation	Years of Experience	Usage Class
P1	Undergrad Student	-	Lurker
P2	Undergrad Student	-	Lurker
P3	Grad Student	-	Active
P4	Grad Student	-	Active
P5	Undergrad Student	-	Active
P6	Grad Student/Industry	2	Active
P7	Grad Student	-	Lurker
P8	Grad Student	-	Lurker
P9	Undergrad Student	-	Lurker
P10	Undergrad Student	-	Lurker
P11	Grad Student	-	Lurker
P12	Industry	1	Lurker
P13	Industry	7	Active
P14	Industry	4	Lurker
P15	Industry	1	Lurker
P16	Industry	10	Lurker
P17	Undergrad Student	-	Active
P18	Undergrad Student	-	Lurker
P19	Industry	10	Active
P20	Industry	-	Active
P21	Industry	10	Active
P22*	Industry	10	Active

person, the determining factor that kept her coming back can be compared to those from the general interviews.

Interview Script To create our interview script, we seeded questions based on potential factors listed in Vasilescu et al.'s work [71], and from reasons listed in a Stack Exchange post titled "Why do you post to Stack Overflow?".[5] We also asked questions about how developers used various features of the site, potential motivations for contribution, and possible interventions.

Subject areas discussed during the interview include:

- Personal usage of the site
- How people communicate on the site
- Interests in gamification of the site
- Personal incentives to using the site
- Response to potential scenarios on the site
- Modifications to the site that may increase usage

Distribution To recruit participants for the usage interviews we sent emails to a "women in computer science" mailing list and recruited females the authors know in computing. The recruitment email asked participants to fill out a preliminary survey asking for their employment status, years of industry experience, whether they used Stack Overflow for programming tasks, and if they had an account on the site. We received 25 responses from the recruitment questionnaire. We required respondents to select a time slot to interview as part of the recruitment questionnaire. We interviewed the 21 participants who attended their scheduled time slot. Interview participants received no compensation for their participation.

We then contacted a high ranked female user on Stack Overflow. This user was ranked in the top 100 users of all time listing.[6] We confirmed the gender of this user with another social networking site linked to her Stack Overflow user page. The 22 participants are shown in Table 1. The participant demographics consisted of nine professional software developers working in industry, twelve students, and one who identified as both.

Procedure Prior to beginning each interview, the participant was sent a consent form to remind them that their personal identity will remain anonymous and that audio and notes will be recorded throughout the interview. For consistency, we conducted interviews with the same interviewer for 30 to 45 minutes. We conducted interviews in a private room where the participant had the option of meeting there or on a private video call.

The high ranked user's interview was conducted after the general user interviews. We scheduled an online video for the interview through email correspondence. With the high ranked user, we discussed several themes that arose from the other user interviews and focused on how her experiences compared and contrasted with other users.

[5] `http://meta.stackexchange.com/questions/18888/why-do-you-post-to-stack-overflow`

[6] `http://stackexchange.com/leagues/1/alltime/stackoverflow`

Analysis We first transcribed the audio recordings for each interview. We then performed three phases of analysis on the interview transcripts. In the first, exploratory, phase we jointly identified themes within the transcripts. The themes we identified in this phase of analysis include statements participants made while describing themselves, statements describing a participant's experiences while programming, and statements describing barriers deterring them from using Stack Overflow. For the purposes of this paper, we focus on the latter theme and refer to these statements as *barriers*.

For the second phase of analysis, we divided all the transcripts divided among three of the authors. Each transcript was examined by two authors. Each author initially coded their assigned transcripts independently, marking statements they identified as barriers. To ensure all the investigators agreed on which statements expressed barriers, we jointly reviewed exemplary statements and revised our codes. In total, we coded 327 statements as barriers.

In our final phase of analysis we grouped together similar statements and labeled each grouping as a distinct barrier. To do so, each author reviewed the barrier statements in their assigned transcripts. Iteratively, whenever an author encountered a barrier statement that did not fit into one of the existing groupings, the other authors reviewed that barrier and created a new label. After completing this process, we filtered out barrier statements that did not meet both of the following criteria.

A barrier was identified if and only if:

- Two investigators independently found that barrier in a transcript.
- At least two participants described that barrier in their interview.

This criteria is consistent with other studies [57]. The 14 resulting barriers are described in Section A and summarized in Table 2.

General Survey We constructed a survey with the barriers identified from the interview participants. The survey consisted of questions regarding the ratings for barriers and demographics. We included all 14 barriers with a statement that further described each one in the survey. The survey presented all barriers in a random order. Survey participants were asked to rate on a 5-point Likert scale from strongly agree to strongly disagree how much the barrier stopped them from contributing to Stack Overflow. Participants also had the opportunity to write in a barrier that was not already listed.

Demographic questions included participants' level of experience on Stack Overflow. Participants had the option of selecting all that applied of: "Lurker (I use the site to find answers without contributing)", "I have a Stack Overflow account", "I post answers to questions", "I post new questions", and "I vote on responses". Participants also had the opportunity to describe their usage in an open-response. We asked participants to fill in their employment status; multiple answers were allowed. The only required demographic question was gender: Female, Male, or Other where participants could write in their gender.

Distribution We distributed the survey to the general developer population. We sent targeted emails, posted to programming forums, contacted large corpo-

rations, and posted in computer science Facebook groups. Survey participants received no compensation for their participation.

Analysis We received data from 1470 participants: 134 females and 1336 males. With the ratings received for each barrier the data was segmented across different populations (including employment status, and Stack Overflow usage). We used the ratings received to derive the collective ranking of barriers per population.

Table 2: Summary of barriers

Group	Barrier
Muddy Lens Perspective	Awareness of Site Features Nothing Left to Answer Fear of Contributing to Clutter No "Good-Answer" Guarantee Perception of Slacking
Impersonal Interac-tions	Fear of Negative Feedback Stranger Discomfort Intimidating Community Size Posting is Hard, Friends are Easy
On-Ramp Roadblocks	Abstraction Process Time Constraints Qualifications On-boarding Hoops Research Pressure

Outcome: Resulting Barriers. To answer RQ1, we identified 14 barriers by jointly tagging the transcribed participant interviews. These barriers are described by participants as reasons they did not contribute to the Stack Overflow community. We are not suggesting that only females would be affected by these barriers, or that the barriers are in some direct way about their gender. However, we are suggesting that barriers to participating in the Stack Overflow community do exist. The barriers are grouped into 3 categories: Muddy Lens Perspective, Impersonal Interactions, and On-Ramp Roadblocks. To the right of each barrier name is the number of participants that acknowledged it. Each barrier described includes a quote from at least one corresponding participant's interview. Table 2 summarizes each barrier and which group they are in.

Awareness of Site Features (11) Stack Overflow provides many features beyond threads for asking and answering programming questions. For example, users can earn reputation and badges, upvote & downvote answers, post bounties, and personalize their profiles. Many of these features are designed to encourage users to interact with the site.

To understand how participants valued the different features, the interview script included scenarios that asked how a participant would use a feature in a

hypothetical situation. For example, we would ask if they might answer more questions if they could gain a badge or edit an incorrect answer. We were surprised that many participants were completely unaware of most of the features we asked about. After learning more about the features, some participants felt more interested in participating in the community. For example, P8 stated, *"No one has told me that creating an account would help a lot. You get some kind of perks by joining. I have not [heard] of anything like that, but had I then, I definitely would have created an account."*

A lack of awareness of potential usage features is a common issue for tools with many features, such as Eclipse [43]. One effective strategy for raising awareness occurs from serendipitous observation of other peers using a new feature [43]. However, for female users there are not many other females or users they can identify with as peers on Stack Overflow. In this case, who will the community recommendations come from?

Nothing Left to Answer (10) Interview participants expressed interest in contributing to the site, but they had trouble finding questions available to answer. The two types of questions found are: (1) those they can answer, but have already been answered and (2) those that are too hard to answer. Between these two options participants expressed that they did not find the opportunity to contribute to the community and lost interest in posting. P2 described her experience searching for questions to answer, *"For a while I'd just try to find questions that I could answer... but eventually, it gets to the point where you're like eh, I'm pretty useless, because all the questions are super hard and all the easy questions have already been answered."*

Fear of Contributing to Clutter (9) Stack Overflow implements mechanisms that discourage users from posting duplicate questions. When a user encounters a question they suspect of being a duplicate, they might typically comment, "This is a duplicate. See *the other* answer". Participants acknowledged that they do not want to make the site any more confusing for other users by adding to the clutter of duplicates. P20 specifically mentioned this as one of her reasons for not contributing, *"I didn't want to add to a bunch of duplicate stuff that wasn't useful... I didn't want to contribute to that issue."*

For some participants, this apprehension prevented them from posting at all. These findings support work done by Preece et al. [53] when studying lurker behaviors.

Similarly, clutter also appears on the site in the form of irrelevant conversations. The conversations can be distracting from the final answer and make users dig through the treasures of the site to find the golden answer they are looking for. P12 described her hesitation to add to conversations, *"I feel like if I don't know why it's wrong, I'm not contributing to the discussion. I'm just adding noise."*

No "Good-Answer" Guarantee (7) Not every question on Stack Overflow gets answered. Participants, like P7, worried that after spending time carefully crafting a question — no one would respond with an answer: *"That's part of the apprehension... that I'm going to post it and I'll never hear back."*

Participants are justified in feeling anxious that the site may not guarantee quality responses: for newcomers, 90% of their questions are answered by themselves [60]. Even when Stack Overflow users respond with answers, participants, like P14, noted their answer quality can vary greatly: *"I think part of [the reason I never signed up] is I've seen so many bad answers on there, like wrong answers."*

Perception of Slacking (4) Stack Overflow is online all the time; developers can contribute during their free time, or while they are at work. Participants with industry positions expressed a hesitation to contribute to the site while at work. They explained that others perceive posting while on the job as slacking, even though learning and helping others on Stack Overflow might be considered a form of professional development. One professional who described this perception was P21, *"I just don't feel comfortable doing it at work. You're deviating from your actual development tasks. And when the timeline is so tight, I try to get in and out and back to what I'm supposed to be doing."*

Fear of Negative Feedback (18) When engaging with peers over the internet, there is always the possibility of coming in contact with internet bullies [13]. These people seem to have no filter when responding to posts online. Some participants perceived the blunt responses of these individuals as rude and argumentative. For example, P1 described the responses to us, *"Have you seen some of the [responses on there]? [They] will just like brutally destroy their answers."*

As opposed to joining, participants, like P5, would rather disengage and question how they can fit in the community, *"It's hard enough to ask for help, then to ask for help and get rude help. You are kind of like, 'never mind'."*

Stranger Discomfort (9) Participants perceived the style of communication on Stack Overflow as blunt and impersonal. Participants identified the lack of females and familiar people as a reason why they felt uncomfortable on Stack Overflow. For example, P20 mentions how the dialogue on the site reminded her of a boy's club, *"I've definitely seen some comments that's not offensive exactly but it feels like I'm walking into a boy's club. You just get that vibe, how they talk."* P20 goes on to mention not feeling welcomed on the site and therefore did not want to engage, *"It doesn't make me feel especially welcome so it doesn't like encourage me to want to post more questions myself."*

P5 also acknowledges "bro humor" and colloquial references in answers as they were geared towards more of a male audience and not her, *"I feel like it's very jokey, but it's in a bro humor type way. The type of things, not to be stereotypical, that guys find funny. And so they usually, in a way, end up objectifying women. Then it makes it weird, because I guess it's funny, but not really, because this affects my life for real."*

P7 reiterated a similar sentiment of discomfort with posting on the site, *"I tend to save the question-asking with people I [know and] feel more comfortable with."*

In other online communities, getting acclimated to the culture as a newcomer [63] can be a difficult barrier to overcome. This is especially true when a group of strangers lack diversity and are not open to the opinion of others.

In summary, the lack of personal connections on the site can discourage females from engaging.

Intimidating Community Size (9) The fact that Stack Overflow is such a widely utilized community was stated to be both a benefit and a drawback for participants. The site is large enough that it has a variety of detailed responses. However, the site is so large that it is hard to identify with the entire community. Participants, like P14, acknowledged that if there were sub-communities of people they actually knew within Stack Overflow they would be more comfortable using the site: *"I enjoy being part of a community as long as they are kind of small. When it becomes kind of a sea of people [it feels] daunting or intimidating."*

Posting is Hard, Friends are Easy (6) Many participants acknowledged that Stack Overflow was a great tool. However, when it came to the opportunity to post to Stack Overflow, there are other painless options still on the table. Participants navigated a hierarchy of increasingly painful options by first going to a friend for help before even considering the most painful option of posting. The interesting finding in this hierarchy is that though asking a friend is usually a last resort, it is seen as a more viable option than constructing and posting a question on Stack Overflow. P2 explained why she preferred asking friends for help, *"I ended up asking other people instead. Other people who could at least explain what is going on."*

Abstraction Process (20) Participants had difficulty asking questions about their code on Stack Overflow. There were two basic problems. Legally, software developers cannot post proprietary code, because they may divulge company secrets. Second, even if they could post all their code, the community may not understand it, because it is so specific to their application, or it would be too long or detailed for anyone to understand. As a result, in order for participants to even ask a question, they first needed to strip a question of all proprietary or unnecessary code. Sometimes this process could be tedious and too much of a burden, and for this reason, they avoided posting questions in general. For example, P11 described the difficulties she encountered with the abstraction process, *"Here's some code. You probably can't run it, because there's like 20 dependencies on it, but just look at it for me and tell me what you think I can do different. For general problems, that's one thing. But for more specific problems, it's a little more difficult to use Stack Overflow"*

Time Constraints (17) In addition to getting familiar with the site, participants expressed a lack of time to interact with the site. There is not enough time to devote to voluntary programming contributions on Stack Overflow beyond the work day. Some participants mentioned other hobbies and interests outside of work they feel are more deserving of their free time; programming was not one of them. For instance, P12 preferred to spend her free time on other activities, *"Actually, I think I would enjoy answering questions on those more if I found one that were more related to my personal interests. Because I strongly associate computer science with work. So it's not something I'd choose to do in my free time."*

Qualifications (13) Some interview participants acknowledged they do not feel they have the expertise to post to Stack Overflow. For example, P1 stated, *"I don't feel like my expertise [is enough] for me to actually post an answer that would be of any help to anyone else."* These participants are not confident in their abilities to interact in the community to help others. In addition, they do not feel like they are qualified to give valuable answers to others. This lack of qualifications and confidence has decreased their interest in contributing.

On-boarding Hoops (9) When joining a new community there is always a process of establishing norms. As frustrating for users as it may be, it is a right of passage that has to take place [17]. A community may have many unspoken expectations on how members conduct themselves. Some participants acknowledged interests in using the site, but were not clear on how. A recent data mining study by Honsel et al. demonstrates that the new users violate site rules more than old users [29]. Not having the proper guidance has discouraged many participants from actively using Stack Overflow. Some participants, P20 for example, are unclear of the norms and rather than asking forgiveness for violating them, they would rather remain reserved, *"I feel like everyone else already knows what it is. And [I] want to stay away from that extra work to figure out how to use it. Just figuring out what the etiquette is, all the little social things too that are kind of unspoken"*

Research Pressure (9) There is a level of research expected to be done prior to posting a question in the community. During the process of crafting a questions, the user is posed with a list of questions that seem similar to the question that user is constructing. This is the site's way of asking, "Have you done your research?" These pressures are reinforced here where it is common for the user to enforce a culture of doing homework before asking a question. Questioning the abilities of users has discouraged some participants, like P4, from posting questions on the site: *"I think there's only one case where I was close to posting a question, but then it said do your research, this question might already be there."*

Outcome: Ranking and Rating Barriers. Although we identified barriers through interviews, we want to identify which barriers can have a strong impact across genders and other groups. By distributing a survey, we can analyze the prevalence of these barriers in a broader population.

The third and fourth authors analyzed the free-form responses from the survey, by independently labeling the response with our 14 barriers or other category. In the analysis, we did not identify a new barrier. With the survey data, we answer our remaining research questions related to the ranking, differences in gender, and influences of other factors on barriers.

Gender Comparison To answer RQ2, we performed a statistical analysis to identify contribution barriers across genders and understand how the populations differed in their response. We performed a two-tailed Wilcoxon rank-sum

Table 3: Statistically significant differences in how females and males rated barriers.

Barrier	p-value	F	M	ES	F Likert
Fear Neg. Feedback	.004	4/4	5/3	0.4	
Fear Contrib. Clutter	.013	4/4	4/3	0.3	
Time Constraints	.497	4/4	4/4	0.1	
Nothing Left	.797	4/4	4/4	0.0	
Awareness	<.001	4/4	1/3	0.5	
Research Pressures	.374	4/4	4/4	0.1	
Posting is Hard	.059	4/3.5	4/3	0.2	
Abstraction Process	.729	4/3	4/3	0.0	
Qualifications	<.001	4/3	1/3	0.4	
On-boarding Hoops	.062	4/3	5/4	0.2	
No “Good-Answer”	.239	3/3	2/2	0.1	
Intim. Comm. Size	<.001	4/3	1/2	0.5	
Stranger Discomfort	<.001	1/2	1/1	0.4	
Percept. Slacking	.001	2/3	1/3	0.4	

test on the ratings given to each barrier to compare populations. Table 3 demonstrates that 5 out of 14 barriers had a statistically significant difference between females and males. To be clear, we are not suggesting that only females are affected by these barriers, or that these barriers are primarily due to gender, but rather that 5 barriers were seen as significantly more problematic by females than by males. The barriers we identified cannot conclusively occur from gender differences alone. All barriers with $\alpha = .05$; $\alpha = .0012$ after Bonferroni correction [75] have been highlighted in green in table 3. This correction was derived by dividing the original alpha value of .05 by the 3 comparisons conducted on each of the 14 barriers. The three comparisons included gender, usage status, and employment status. In table 3, 5 is used to indicate strongly agree and 1 for strongly disagree. The columns labeled F and M indicate the mode/median for females and males respectively. For example a value of 3.5 indicates a response between neutral and agree. The column labeled ES indicates the effect size which was calculated by taking the absolute value of subtracting the mean of the male distribution from the female distribution. The last column indicates the likert distribution for females from strongly agree to strongly disagree. The table is order from greatest to least agreement(combining strongly agree and agree ratings) for females. A diverging stacked bar chart comparing the distribution of barriers for females and males is also available online.[7]

Additional Factors We understand that confounding factors, other than gender, may also affect Stack Overflow participation. For example, online interactions and programming experience could play a role. To answer RQ3, we review

[7] `http://go.ncsu.edu/StackOverflowBarriers`

a few of these factors using a statistical analysis to compare how barrier ratings varied across Stack Overflow usage and employment status.

Usage Status. This analysis compared the participants who reported having a Stack Overflow account *(n=1003)* to those who did not *(n=467)*. We observed statistically significant differences (Wilcoxon rank-sum test with Bonferroni correction $\alpha = .0012$) between account holders and non-account holders ratings of seven barriers. In all seven cases, non-account holders were more likely to identify with a barrier. Specifically, non-account holders were more likely to identify with the following barriers (listed in order of smallest p-value to greatest): *Awareness of Features*; *Stranger Discomfort*; *Intimidating Community Size*; *Fear of Contributing to the Clutter*; *Posting is Hard, Friends are Easy*; *Qualifications*; and *On-boarding Hoops*. These barriers suggest places where effort can be focused to encourage lurkers to join.

Employment Status. We also compared survey responses from those who identified as full time developers *(n = 1003)* to those who did not identify as such *(n = 467)*. We observed statistically significant differences (Wilcoxon rank-sum test with Bonferroni correction $\alpha = .0012$) between full time developer and non-full time developer ratings of two barriers. We found that fulltime developers were more likely to identify with *Time Constraints*. On the other hand, the non-full time developer group were more likely to identify with *Qualifications*.

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