ABSTRACT

FORD, DENAE. Identity-Based Signals and E-Mentorship to Support Engagement in Online Programming Communities. (Under the direction of Dr. Christopher Parnin).

Online programming communities, a type of socio-technical ecosystem, enable a peer support cycle where software developers can receive technical guidance from other developers who encounter similar issues. With over 23 million software developers in the world, these communities are helpful for gaining a global perspective on a range of complex programming problems. Communities such as Stack Overflow and GitHub have a global reach of over 10 million and 37 million registered users, respectively. These numbers do not take into account the large number of users without registered accounts—who are able to derive a high utility from these platforms.

Despite the many advantages of engaging in these communities, developers who identify as novices and underrepresented groups do not. According to global annual developer surveys, women are less than 8% of the community and less than 2% are non-binary. Similar distributions occur when referring to race and ethnicity: the majority of contributors to these communities are White or of European descent (70%). Likewise, novice programmers—forming a third of the community with less than 5 years of experience—continue to lurk and express interest in participating but face challenges finding opportunities to contribute. The existing mechanisms in place to engage these users often focus on getting developers to the platform or creating a new one altogether. But how can we invite developers to engage in a community that is already broken? My approach focuses on understanding and building new community mechanisms to create a more inclusive online programming community.

The goal of this research is to investigate inhibitors to engagement in online programming communities using the conceptual framework of barriers. The conceptual framework of barriers are split into two groups: social barriers—obstacles that limit the social interactions users seek and cognitive barriers—obstacles that lead to cognitive burdens users with endeavors to engage in the community encounter. Using this framework as a roadmap of challenges users face, I derive interventions to support engagement.

The thesis of this dissertation is that 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, introducing mentorship, and understanding sub-communities, we can help programmers overcome these barriers and significantly increase participation in online programming communities. Through the conceptual framework of barriers, this dissertation understands and build mechanisms of how barriers can be reduced and engagement increased in four studies:

1. To learn how identity can encourage engagement, I conducted an empirical analysis of post and user data on Stack Overflow of women helping other women. I found that only 32% of identifiable women have ever posted a question. I also found that women who experience peer parity were more likely to engage sooner.

2. To learn how e-mentoring can influence engagement, I crafted a collaborative, formative feedback forum on live Stack Overflow. I find that with just-in-time mentoring, I reduce negative experiences for participants and improve community receptiveness to novice contributions. I found that mentored questions provided feedback that improved novice's question quality. I found that the average question score increased over 50%, and novices were extremely satisfied with their mentorship experience.

3. To learn how barriers are influenced by sub-communities, I conducted a study immersing software developers in a Stack Overflow Team instance while they worked on their software projects and monitored their activity. I found that while most developers did not ask questions, their perspective of these barriers inhibiting their participation was influenced. I also found that having an offline relationship with online community members increased trust and belonging to the community.

4. To learn how identity signals are used in contributing code in online programming communities, I designed an eye-tracking experiment with programmers as they reviewed pull requests. I examined if and how supplementary technical details such as previous contributions, and socially identifying connections such as the avatar image, are used when making decisions about code contributions. I found that even when they do not think they are, programmers consider social signals of users when asked to review code contributions.

This dissertation concludes with implications for this work and future directions that lead towards explicit mechanisms to transfer offline acquaintances into online sustained bonds, create systems that encourage guidance or e-mentoring with close proximity to a shared identity, and building community infrastructure support sub-community and micro-community engagement.

Identity-Based Signals and E-Mentorship to Support Engagement in Online Programming
Communities

by
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DEDICATION

To Frederick and Audrey, the sages.

To Wayne and Deidre, the tacticians.

To Joshua, Ethann, and Matthew, the cheerleaders.

To Nicholas, the inquisitor.

To Brianna, the pacemaker.

To Ryan, my rock.

BIOGRAPHY

Denae Ford obtained her high school diploma from the Science and Technology Magnet Program at Charles Herbert Flowers High School in Prince George's County, Maryland. To achieve this diploma she had to successfully pass her Research Practicum in Computer Science, in which she was honored with top accolades for her project. Denae went on to continue her passion for Computer Science at North Carolina State University. During her time with the Wolfpack, Denae balanced a competitive NCAA Division 1 track and field career, served as president of Sisters in Sports, vice president of Women in Computer Science, and conducted undergraduate research with Dr. Kristy Boyer. In the Spring of 2014, just 4 years later, Denae received her Bachelor of Science Degree in Computer Science with honors.

Following the interest in research re-ignited by her work on artificially intelligent tutoring systems, she pursued her Ph.D. in Computer Science at North Carolina State University under the supervision of Dr. Christopher Parnin. Fascinated by the cognitive demands of software development, Denae obtained her Master of Science in Computer Science with a minor in Cognitive Science in December of 2016. Throughout her academic career, Denae has interned and collaborated with research laboratories and technology companies including: SAS Institute (2013), MIT Lincoln Laboratory (2014 and 2015), Microsoft Research (2016), Stack Overflow (2017-2018), and Facebook Research (2017).

Denae's continued interest of who the builders of technology are and how they overcome challenges driven her research at the intersection of human-computer interaction, software engineering, and socio-technical ecosystems.

ACKNOWLEDGEMENTS

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1

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**, introducing **mentorship**, and understanding **sub-communities**, we can help programmers overcome these barriers and significantly increase participation in online programming communities.

CHAPTER

2

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. Programmers 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 [120], 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 [76] while contributing to the code of others [128].

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 [77], which pales in comparison to the 20% of Stack Overflow that are women [119]. 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 [128]. Women and underrepresented groups are virtually absent from online programming communities, even though they comprise about 20% of the software engineering field [61]. For example, David et al. found that women make less than 5% of all open source contributions [23]. There are several theories to explain these low participation rates. Often women do not feel

welcomed in these online communities [114] and overall are unfamiliar with community culture and expectations [1, 101], 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 [120], 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 [96]. 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 [87]. 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 [46].

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 [41]. 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 or sub-community, can help users feel more comfortable participating in online programming communities and other socio-technical ecosystems.

2.1   Motivating Example

To further understand the process of contributing to an online programming community, I 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

Figure 2.1 Writing a question to post on Stack Overflow.

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 2.1. 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 this dissertation, I will discuss research that investigates barriers to participation programmers encounter in online programming communities and motivate research using a conceptual framework to dismantle them.

2.2   Contributions

The contributions of this dissertation defend the thesis statement presented in Chapter 1:

> *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, introducing mentorship, and understanding sub-communities, we can help programmers overcome these barriers and significantly increase participation in online programming communities.*

To defend the claim that "online programming communities do not make the contribution process inclusive for novice and underrepresented programmers due to social and cognitive barriers," I offer evidence in Chapter 4 to support:

- *A conceptual framework* for what prevents programmers from participating in online programming communities. This framework outlines social and cognitive barriers (Chapter 4).

To defend that "incorporating identity-based signals we can help programmers overcome barriers and significantly increase participation" I conduct studies that can be found in Chapter 6. I find that:

- Of the women identified, only 32% have ever posted a question.

- The default user experience for women is low access to peers—most threads only have one woman.

- Women who experience peer parity were more likely to engage sooner.

To defend that "introducing mentorship and understanding sub-communities" can influence participation I conducted two studies in Chapter 7 and Chapter 8. From those studies, I present:

- *A proof-of-concept mentorship program* to demonstrate community impact and feasibility of self-sustaining support (Chapter 5). This program indicates that it is feasible and practical to use identity-based interventions in a mentorship program to increase participation.

- Participating in a private, specialized sub-community allowed for more opportunities to contribute.

- Having an offline relationship with online community members increased trust and belonging to the Stack Overflow community.

2.3 Outline

This dissertation can be read as follows:

Chapter 3 identifies background literature supporting the framework and research areas supporting this body of work.

Chapter 4 details the empirical investigation of the social and cognitive barriers.

Chapter 5 outlines how these barriers can be used as a framework for understanding how to build and study interventions in online programming communities.

Chapter 6 presents the concept of *peer parity* and studies how women answering questions from other women can influence participation on Stack Overflow.

Chapter 8 studies how the use of a private sub-community where users have an offline relationship can influence participation.

Chapter 7 demonstrates a proof-of-concept mentorship program for novices to receive help from an expert user. This takes place in a sub-community where users do not explicitly have an offline relationship.

Chapter 9 provides an empirical investigation of interpreting signals of identity on other online programming communities, such as GitHub.

Chapter 10 outlines conclusions, implications, and describes the future work that can evolve from this dissertation.

The appendix to this dissertation includes supplemental details of on the conceptual framework of barriers and the studies that identify interventions to dismantle them.

CHAPTER

3

BACKGROUND

3.1 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 [112]. 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 [51]. These factors also present four fundamental problems of socio-technical ecosystems: architecture, business opportunities, coordination, and governance [51]. In this work I 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 [84]. 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.

3.2 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 [63]." 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* [121]. In this work, I study how mutual engagement can influence newcomer participation in online programming communities as a community of practice.

3.3 Sub-Communities

The locality of sub-communities can provide community members with a space to feel comfortable within a larger community. In information and communication technologies, Erete and Burell have demonstrated how how online sub-communities can effectively influence offline local governance and empower community members to use their voice [29]. Likewise, Morgan and Filippova

contextualize how the norms in online sub-communities of Wikipedia have transferred from perceptions of the community-at-large but can also be influence to shift behavior [71]. These works are helpful in understanding a variety of approaches on how sub-communities can be a vessel for engagement, but do not explicitly describe how sub-communities can help transfer member engagement to the community-at-large.

The context of online communities has redefined how sub-communities are situated within the community-at-large. Specifically, larger online communities are helpful for having access to breadth of people, but also places barriers on the access the depth of individual interactions with community members that can be had. Sub-communities give users the access to both; especially when the sub-community is embedded within the context of the larger community. These spaces can be private or public and can even offer transition machinery for participants to get acclimated to the community-at-large and to tangential sub-communities. In this dissertation, I place a lens on how sub-communities of online programming communities provide a space for members to implicitly embrace homophily and encourage engagement.

3.4   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 [111]. 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 [127]. Hunt and Hillery found a significant difference in performance among women performing a complex task with other women as actors [54]. 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.

3.5   E-mentoring

E-mentoring can encourage programmers to 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 [13]." In socio-technical ecosystems, e-mentoring can impact participants by enhancing technical skills and forming interpersonal relationships [109]. In this

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work, I study the effects of introducing e-mentoring in an online programming community.

3.6   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 [91]. Of course, systemic factors already in effect can deter a fully inclusive community, but 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 [91]. In terms of online programming communities, the lack of inclusive participation in the community has encouraged characterizations with many approaches [65, 77, 119]. 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 [118] and identify barriers as to why it may be so hard for underrepresented groups to contribute [41]. This presents an opportunity to explore these challenges and devise approaches to facilitate a more inclusive online programming community.

3.7   Research Overview

Taking the aforementioned into account, my research studies 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 describe interventions to increase how programmers participate online: 1) identity-based signals, 2) mentorship, and 3) sub-communities. The following chapter outlines an empirical investigation of barriers to participation in online programming communities.

CHAPTER

4

EMPIRICAL INVESTIGATION OF BARRIERS AND IDENTITY

In this chapter, I describe a conceptual framework to identify how programmers face barriers when contributing to online programming communities.[1] 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.

4.1 Study Rationale

To create this framework, I interviewed and surveyed programmers about their participation on Stack Overflow. I 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

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[1]Significant portions of this chapter were previously published as D. Ford, J. Smith, P. Guo, and C. Parnin, "Paradise Unplugged: Identifying Barriers for Female Participation on Stack Overflow" in *ACM SIGSOFT International Symposium on Foundations of Software Engineering (FSE)*, 2016, pp. 846–857

work, but not yet explained. I sought to understand the relationship between barriers through factors such as gender, participation level, and professional development experience.

4.2   Methodology

To discover what barriers Stack Overflow users encounter, I use a mixed-methods approach. I conducted semi-structured interviews with 22 women developers in order to understand what prevents them from actively participating on the site. My focus was on women because I wanted to understand the obstacles they face and identify possible solutions. I 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, I identified 14 barriers based on common experiences of participants. To validate and understand how these barriers might differently affect both women and men users, I sent a survey to software developers, receiving responses from 134 women and 1336 men. From the survey, my collaborators and I identified which barriers women and men face and which ones are gender-specific.

4.3   Barriers Identified

I identified 14 barriers to contributing in online programming communities. For the purpose of this work, my collaborators and I 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 I 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. 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.

4.4 Identity-Based Participation

To find how identity can dismantle barriers to participation online, I conducted a qualitative study on the perceptions of the #ILookLikeAnEngineer identity hashtag movement [66]. To counteract engineering stereotypes, the movement called for engineers to post selfies with the hashtag on social media sites [106]. I 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.

CHAPTER

5

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 I 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.

5.1   Using Identity-Based Signals to Increase Participation

One barrier I 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 [41]. 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, I 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 [66]. 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.

5.2   Using Sub-Communities to Increase Participation

Two barriers I target to increase participation is *Intimidating Community Size* and *Stranger Discomfort*. Within sub-communities, explicitly situated within online programming communities, I understand how the actual reduced community size and familiarity of a community can influence members. In communities-at-large, many new users are likely to make mistakes that will result in public negative criticism [33] 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 [41]. In designing a private sub-community with known members, community members can make mistakes in a setting that they can feel comfortable learning from.

5.3   Using Community Mentorship to Increase Participation

Another barrier I focus on to increase participation is *Fear of Negative Feedback* and *Onboarding Hoops*. With a mentorship program I 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 [28]. 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, I can increase the promptness and effectiveness of the feedback given.

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* [121], 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 first experiment of this dissertation, a study of participation of women on Stack Overflow

CHAPTER

6

PEER PARITY

Several challenges exist that can explain low participation rates. In chapter 4 subjects mentioned that one reason they do not post on Stack Overflow is that *"They are just not even on the same race track [41]."* This theory of observing people on the same "race track" or having similar individuals to compare oneself to is known as *peer parity*. Other challenges include asking a question as users may be uncomfortable revealing that they do not know something. Similarly, asking can give the perception that a person may seem pretentious as they display their knowledge on a topic that others lack [74]. How users phrase a question matters—emotional tones of technical questions can influence how they get answered [75]. Often times questions lacking the affect expected from community users may not get answered. These are all factors that may cause the user who asked a question to feel they do not belong; discouraging them from participating at all and encouraging lurker behavior [43].

I define *peer parity* as:

> *When an individual can identify with at least one other peer when interacting in a community.*

Peer parity can exist across and within races, genders, experiences, career positions and more. In this work, I study peer parity among identifiable, perceived genders. Based on studies of identity and peer interactions [43, 105], I hypothesize that differences in exposure of peer parity may influence participation in online communities such as Stack Overflow.

In this chapter, I study peer parity to understand how being on the same "race track" as other women can affect participation.[1] I extracted both post and user data from Stack Overflow. After analyzing the genders of the participants on a question using their display name I identified posts where many women are on a thread and compare this to instances where there is only one woman. I then analyzed questions asked by women who were exposed to parity and non-parity and found a significant difference in engagement. To make my findings actionable, I provide implications for researchers and online communities. Specific findings from this work are:

- Of the women identified, only 32% have ever posted a question.

- The default user experience for women is low access to peers—most threads only have one woman.

- Women who experience peer parity were more likely to engage sooner.

6.1 Motivating Example

I offer the stories of two users with different experiences to give an example of how peer parity may influence participation in the context of Stack Overflow. Olivia is providing an answer to a question she has experienced herself in the past. After looking through the listed answers to a Stack Overflow question she found, Olivia thought the solution she derived worked better. Before she posted an answer she decided to double check other answers that are shown. After she scanned the names and determined that many of the answers are from women, she feels encouraged to see users she can identify with. Olivia then proceeds to post her answer.

Another user Mellie, had a similar scenario, although it did not end as successful as Olivia's. Mellie also identified a question where she had an alternate answer and expressed interest in posting. Mellie scanned the names of the other user answers and determined many of them may be men. She could not identify any other women on the post, therefore Mellie decided not to post her answer. I want to understand if scenarios such as those Olivia and Mellie encounter effect their interest in posting on Stack Overflow.

6.2 Background

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

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[1]Significant portions of this chapter were previously published as D. Ford, A. Harkins, and C. Parnin, "Someone Like Me: How Does Peer Parity Influence Participation of Women on Stack Overflow?" in *IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, 2017, pp. 239–243

6.2.1 Stack Overflow Participation

Stack Overflow has a participation problem and researchers notice. Slag et al. found that the majority of Stack Overflow users make one contribution and stop using the site [96]. The density of poor quality and unguided questions has increased the number of deleted questions over the past two years. Xia et al. noticed the increase in deleted questions and determined an algorithm to predict this occurrence and get ahead of the issue [124]. However, deleting questions does not necessarily solve the participation problem, it actually dismisses it. In this work, I chose to study this participation problem through women and determine whether women asking questions among peers will effect their activity moving forward.

Women participation on Stack Overflow is valuable, yet barely exist according to community builders and researchers. In addition, the site's lack of diverse participation has encouraged much interest in characterizing it with many approaches [65, 77, 119]. All of these studies reach a similar conclusion: women are discouraged to participate on Stack Overflow. In an effort to explain why, researchers have shown that men represent the vast majority of contributors on Stack Overflow [118] and identify barriers as to why Stack Overflow may be so hard for women to contribute [41]. Taking the aforementioned into account, I chose to investigate where the few women in the community are and how and if they are supported by the interactions of each other.

6.2.2 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 [100]. 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 [94]. In addition, Archdivelli et al. found many cultural differences in sharing identity online across many countries within the same context [4]. Building on this, I 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 [74]. However, what can encourage users to post online and use their identity is knowing that they are not the only person being vulnerable [98]. In this work, I hypothesize that some women may seek a community of peers that they can identify with.

6.2.3 Diverse Peer Influence

Ichinco et al. identified that community members becoming leaders can influence who users identify with in a community [55]. 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 received access to teachers that resembled them, those students were more likely to go to college and seek similar career paths as their teachers [43]. In addition to race, I 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 [18, 42]. 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 [120]. Intergroup relation theorists have identified that there is a strong cognitive preference for women among women in terms of identity [93]. Ford outlined an application of the Bechdel Test to determine how presence can effect a women on Stack Overflow [37]. In my work, I demonstrate that an in-group preference among women may exist in online programming communities.

6.3 Methodology

My work is guided by the following research question:

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

Prior work demonstrates individuals who can identify with other members of community will increase interest and engagement while those who do not identify with the community lose interest [105]. On Stack Overflow it is challenging to find identities that may resemble a minority; users have mentioned difficulty finding other women [123]. I hypothesize that peer parity would have an influence on how women posted on Stack Overflow and that women on the parity posts have more activity after participating on a parity thread. To determine if there is a difference among the community, I compare differences in posting activity between women who experienced peer parity and those who did not.

6.3.1 Data Extracted

I extracted 5,987,284 users and 32,209,817 posts from the Stack Overflow Data Exchange. The oldest post of the data I studied is July 31, 2008 and the latest is September 4, 2016.

6.3.2 Identifiable Genders

After I gathered all threads I identified genders of the users based on their display name with Vasilescu et al. genderComputer Tool [119]. The reported precision of genderComputer is about 90%. I 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 my tool having higher precision in determining genders. The tool reports the gender of the user as male, female, unisex, or undetermined. In my work, I report females as women and males as men. With my modified tool, I 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 [48].

6.3.3 Peer Parity Defined

In this work, I determined that peer parity exist if there is more than one distinct woman on a thread. I refer to this as *parity*. Otherwise, I describe threads that only have one distinct woman as *non-parity*. To clarify, I do not specifically isolate posts with only women. From my extracted data I was only able to identify 32% of all identifiable women who have ever posted a question.

6.4 Findings on Stack Overflow Peer Parity

To investigate my research question, I first randomly selected 1000 women who have ever posted more than one question. Second, I gathered their first question and their second posted activity. Third, I identified the time difference between activity. I selected women who have asked questions to control for a shared first experience on the site. I calculated the gender of all users on a thread and identified whether their first question was on a parity or non-parity thread. I used the time difference between their first question and second activity as a comparison of how soon they re-engage in the community. I also identified the reputation points and number of badges for each of the women. I used the number of reputation points, which are a measure for how much the community trust users, as a measurement for frequency of activity [79]. The number of badges is one way Stack Overflow demonstrates positive user activity [78]. Both the number of badges and reputation points are also visible next to a user's name when posting a question or answer.

Of the 1000 randomly selected women, I identified 452 parity and 548 non-parity threads from their first question. I found a significant difference in type of second activity after participating on a parity or non-parity thread (p = 2.799e-06, α =.05), which was either posting a question(N = 833) or posting an answer(N = 167). I 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 = 1.83e-05,
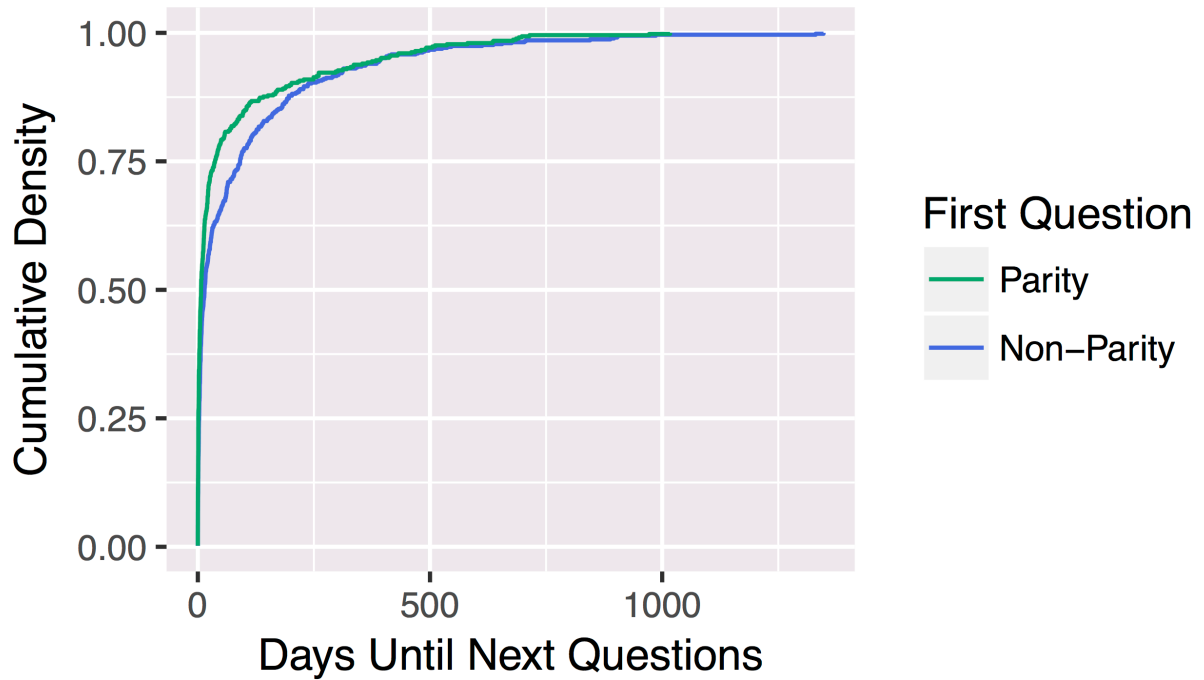
Figure 6.1 The time between activity for parity and non-parity threads. The x axis indicates a time difference in days until their next activity after either posting a question on a parity or non-parity thread. The y axis indicates the cumulative frequency of within that time frame. This graph demonstrates that women-askers participating on parity thread have post more immediately after participating on non-parity thread.

α =.05). The cumulative time differences by posts are demonstrated in Figure 6.1. This figure demonstrates that the longest time difference for a parity activity was 1017 days and 1347 days for a non-parity activity. I did not find a significant difference in reputation points or number of badges. I observed a small effect size among the comparison of time differences(d = .1), reputation(d = .1), and number of badges(d = .2).

These statistical differences are supported by all second activity from parity threads being completed before non-parity threads as shown in Figure 6.1. These results demonstrate that women who are on parity threads engage sooner in Stack Overflow participation activities.

Finding: Women who asked questions on parity posts reengaged sooner. However, they do not have higher reputation.

6.5 Discussion

From my findings I determined factors that can be implied from this work through the explicit use of identity and how that can fuel a mentorship program through peer parity. I also provide suggestions on how we can encourage a user's growth and redefine what the best mentors should do based on peer parity [108].

Showcasing success: According to the developer survey, the number of women on Stack Overflow has increased from previous years and, likewise, Stack Overflow has been quite vocal in fostering a more inclusive community [77]. The very idea of being transparent about a community problem may have played a factor in the increased interest in the site. Perhaps one way to inspire and increase others to participate is to showcase top-rated questions asked by women. In addition, a series could be launched to showcase these top-rated users where new users can learn how top-rated users have come to be recognized for their contributions to the community. This will not only demonstrate how to post successful questions of Stack Overflow, but also shows the diverse set of users contributing.

Paired guidance: Asking for help can be hard; but it can be easier if a peer is available to help. In my work, I noticed that women in the presences of peers reengaged sooner. If a user is about to post their first question online, it may be a good opportunity to approach them in the act and let them know there is a group of users willing to offer guidance. As I found that peer parity exist, I recommend mentor-mentee pairing based on peer identification to further expand engagement. Mentorship is a bidirectional relationship—both parties have something to gain. Encouraging users to seek guidance can benefit both the mentor, providing guidance, and the mentee, seeking guidance. Mentors in this community can decide on the varying degrees of their engagement based on their popular use of similar tags that a mentee may add to their question. For example, mentors can be hands on and help users write and edit questions incorporating that tag. In contrast, a mentor can be hands off and offer advice on how to gain the most utility from community users who are answering similarly tagged questions.

Revealing user identity: My work shows that users may be interested in seeking an identity they can relate to and feel comfortable with online. There has been much objection to Stack Overflow's stance to not explicitly requesting identifying information such as gender. However, my work builds on the idea that there are features of user identities that users are interested in sharing, but not given the opportunity to. When there is not a platform to support the multiple layers of identity that users have, an organization is saying they are *not* interested in hearing about that identity of a user. This inadvertently demonstrates organizations taking a stance on the topic and saying it does not matter. However, it can be difficult for users to separate from their identity in public spaces, furthermore, they should not have to. The same layer of identity that Q&A resources omit, may be the same feature of identity that effects

their lack of diverse community engagement. We should embrace and support users who wish to disclose this information. Similarly to other identity features users can enter in their account profile, such as a birth date and full name, it is should be a common practice to provide the option for users to enter their gender. Allowing users the opportunity to bring their whole self into a community where they seek help may just be the encouragement they need to be active contributors.

6.6   Threats to Validity

Construct Validity. There are few women on Stack Overflow according to the developer survey and previous research declared it hard to determine the gender of individuals. I cannot say that I captured all the profiles of women on Stack Overflow. Further analysis will have to be done to confirm identities.

Internal Validity. I isolate users in this experiment. This may cause us to focus on threads where women are very active. I may have had a more representative experiment had we confirmed the scores of the threads and the number of users on each thread.

External Validity. I may have issues adapting to other programming communities. Stack Overflow has many features of activity on a thread including visible reputation of users, questions scores, and answer scores that other programming help communities do not offer on the same page.

6.7   Conclusion

Stack Overflow is a resource that programmers use to fix their programming issues and learn how others work through similar issues. However, there is an difference with who can contribute to those programming solutions, specifically women.

In this chapter, we introduced a concept called *peer parity*. I adapt the concept of finding "someone like me" to how women may identify with other women on Stack Overflow. Using first names as identifiers as a gender, I define parity as instances where there are many distinct women on a thread and non-parity as threads that have only one distinct woman. I find that although there are less women participating on parity threads, the women on parity threads reengage sooner in the community. This finding presents a gateway to future mentorship programs. I discussed interpretations of these findings and describe interventions to understand how being among like minded peers can increase engagement in online programming communities. After all, you cannot be what you cannot see.

In the next chapter, I discuss how identity may take a role in sub-communities.

CHAPTER

7

COMMUNITY E-MENTORSHIP PROGRAM

7.1 Introduction

For Stack Overflow, "hostile" criticism and conflict [41, 119] is especially problematic for prospective members. As a result, a user may decide not to ask or answer a question for *fear of negative feedback* [41]. These problems can dissuade novices [101] and women [119] from participating in the community. On the other hand, active community members are interested in preserving community norms: not allowing duplicate questions, off-topic or non-closed questions, or poor quality answers. Community members need a mechanism for helping new users ask better questions, while reducing the hostility and negativity of otherwise well-meaning feedback.

In this chapter, I apply theory related to learning and communities of practice to a social Q&A site, by using methods related to mutual engagement and formative feedback to improve novices' questions.[1] Building on design claims for increasing engagement in online communities [59], I created *Help Rooms* with collaborative question drafts to enable novices to receive timely and formative feedback from mentors before posting their questions. My *Help Rooms* work as follows:

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[1]Significant portions of this chapter were previously published as D. Ford, K. Lustig, J.Banks, and C. Parnin, "We Don't Do That Here: How Collaborative Editing with Mentors Improves Engagement in Social Q&A Communities" in *ACM CHI Conference on Human Factors in Computing Systems (CHI)*, 2018, pp. 608:1–608:12

when a novice is about to post a question, they are asked if they want additional feedback from a mentor. If the novice responds positively, they are redirected to a room with a mentor who can help them edit their question. The mentor offers advice on how to phrase and ask their question so that it can be well received by the Stack Overflow community.

The primary contributions from this study are:

- A novel, just-in-time mentoring mechanism that reduces negative experiences for novices. While existing mechanisms and guidelines provide novice support, such as collective socialization through FAQs, mandated virtual training, and formal guidance, my just-in-time mentorship mechanism provides guidance at the critical moment when novices are about to submit a first-time contribution to the community.

- An investigation of how formative feedback novices receive in a private *Help Room* can reduce the negative experience caused by delayed or negative feedback. My overall contribution is also novel in that I explore novice mentorship in a context not evaluated in previous related work: adapting existing mechanisms of a large, technical Q&A community.

- An empirical evaluation demonstrating that with just-in-time mentoring, I can reduce negative experiences for participants and improve community receptiveness to novice contributions.

Overall, my findings support how researchers and practitioners studying other communities of practice and social Q&A sites can apply design claims from prior work and measure interactions.

7.2   Background

I explain online community mechanisms, theories they follow, and how Stack Overflow is a model community to increase novice engagement.

7.2.1   Online Community Mechanisms

Online Q&A communities have mechanisms to organize and annotate content. Stack Exchange is a network of sites that incorporates these mechanisms into a variety of communities [32]. Technical users find themselves on Stack Overflow, one such community in the Stack Exchange network, by searching for answers to programming-specific obstacles. When users fail to find the answers they need through searching, they pose their own questions to the community. Similar to most online communities, questions and answers on the site are rated and ranked using scores calculated by upvotes and downvotes from community users [67].
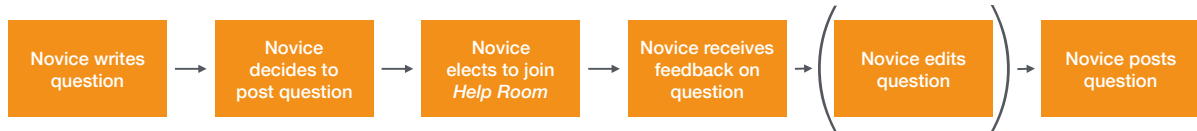
Figure 7.1 The flow of how eligible novices participated in the *Help Room*.

7.2.2 Theory and Concepts in Practice

Stack Overflow fits well within the community of practice framework. A *community of practice* is defined as "groups of people informally bound together by shared expertise and passion for a joint enterprise [63]." The term has been used very broadly to include anything from interest-based forums to professional networks on email lists or technical support forums. Stack Overflow can be understood as a community of developers bound together by a shared interest in 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 in 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* [121].

7.2.3 A Call for Mentorship

I focus on Stack Overflow not only because it has the most traffic of all Stack Exchange communities, but because of its transparency as it relates to the quality of the user experience [77]. Many questions from novices are ill-received: downvoted, left unanswered, or deleted [5]. 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 [41]. I hypothesize 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 this community and others like it.

7.3 Collaborative Editing with Mentors

As a first step in supporting my long-term goal of creating a mentorship platform for Stack Overflow, I built a *Help Room* targeted at novices in the community. One of the most common

problems for new users is difficulty asking questions [41]. The new feature introduces two core components: 1) A collaborative question draft, and 2) a private *Help Room* where new users can chat with mentors to discuss and edit the draft. I describe the principles I used to guide this design and describe how it can be used on the site.

7.3.1 Design Principles

7.3.1.1 1) Provide formative and timely feedback

Users who have enough reputation points on Stack Overflow can provide feedback using existing site features in two ways: (1) commenting on questions to suggest improvements or ask for clarifications, and (2) directly editing other questions or answers on the site. While these mechanisms can be effective means of content curation, the feedback received from these mechanisms is limited. First: comment conversations are slow, often taking hours or days, which reduces the effectiveness of the feedback [28]. Second: question edits may occur without the knowledge of the asker, which limits the opportunity for the asker to improve the question themselves. With this principle, I actualize Kraut et al.'s design claim to encourage contributions by coupling the timely goal of posting a question with the ability to receive frequent feedback [59].

7.3.1.2 2) Allow mistakes in a private space

Many new users are likely to make mistakes that will result in downvoted or unanswered questions, causing their already low reputation score to suffer. Further, receiving harsh or negative criticism [33], especially in public or professional settings [9], reduces the effectiveness of the feedback itself and increases the chances the prospective member will disengage from the community [41]. I include this design principle to build on prior work which suggests that novices may be more likely to learn and participate in a smaller group within a community [59].

7.3.1.3 3) Do not answer questions, help others ask better questions

Not only the existence of a mentorship program, but also the approach, are critical to increased learning and engagement. In designing mentors' roles, I clearly delineated their responsibilities versus those of the community at large: mentors provided feedback on the questions, but not the answers to the questions. By working together on improving questions, novices and mentors participate in *mutual engagement* [121], an effective method for onboarding new participants in a community of practice. I include this design principle in accordance with Kraut et al. in order to increase members' knowledge of community expectations and how to follow them [59].

7.3.2 Feature Implementation

I used an existing Stack Overflow chat room feature to support my implementation. Site rules dictate that users can only participate in chat with 20 reputation points or more, so for my study, I modified specific rooms to remove that barrier for eligible novices (users with fewer than 15 reputation points and fewer than 3 questions). 15 reputation is a key threshold for several on-site privileges and represents no more than 3 total upvotes received.

I created two types of chat room: 1 *Private Mentor Room* and 4 *Help Rooms*. Novices are directed to the least-recently-used *Help Room*, where they are greeted with an automated message describing the chat room and then joined by an online mentor. Novices are only provided the option to join a chat room if mentors are present in the *Private Mentor Room*. The *Private Mentor Room* serves several purposes: 1) notify mentors of novices entering the *Help Room* with draft questions, 2) allow mentors to declare which novice they would help, and 3) allow mentors to discuss challenges with each other and with study designers.

When a novice joins a *Help Room*, their question draft is shared with the *Private Mentor Room*. Collaborative question drafts are only editable by the posting user, but can be viewed by all users within the chat room. Similar to the existing "Ask a Question" page on Stack Overflow, the collaborative draft editor uses Markdown, a lightweight markup language, for formatting. Each time a draft is edited, an in-line notification that links to the updated draft is shown.

7.3.3 Feature in Action

Collaborative drafting in a chat room offers a platform where mentors and novices interact to devise better questions. To offer a better understanding of how both use this tool, I describe how Mason, a novice user, and Issa, a mentor, used help rooms. Figure 7.1 further demonstrates the collaborative question draft feature in action.

7.3.3.1 Prompting Novices

Mason has encountered a programming problem while creating arrays in JavaScript. In need of some help, Mason decides to ask his first question on Stack Overflow. He drafts his question to be posted online and clicks the [Post Your Question] button. Mason is given an option to either post his question to Stack Overflow or chat with a more experienced user who can help him refine his question (Figure 7.2). He clicks the button that reads: [Yes, join mentorship chat].
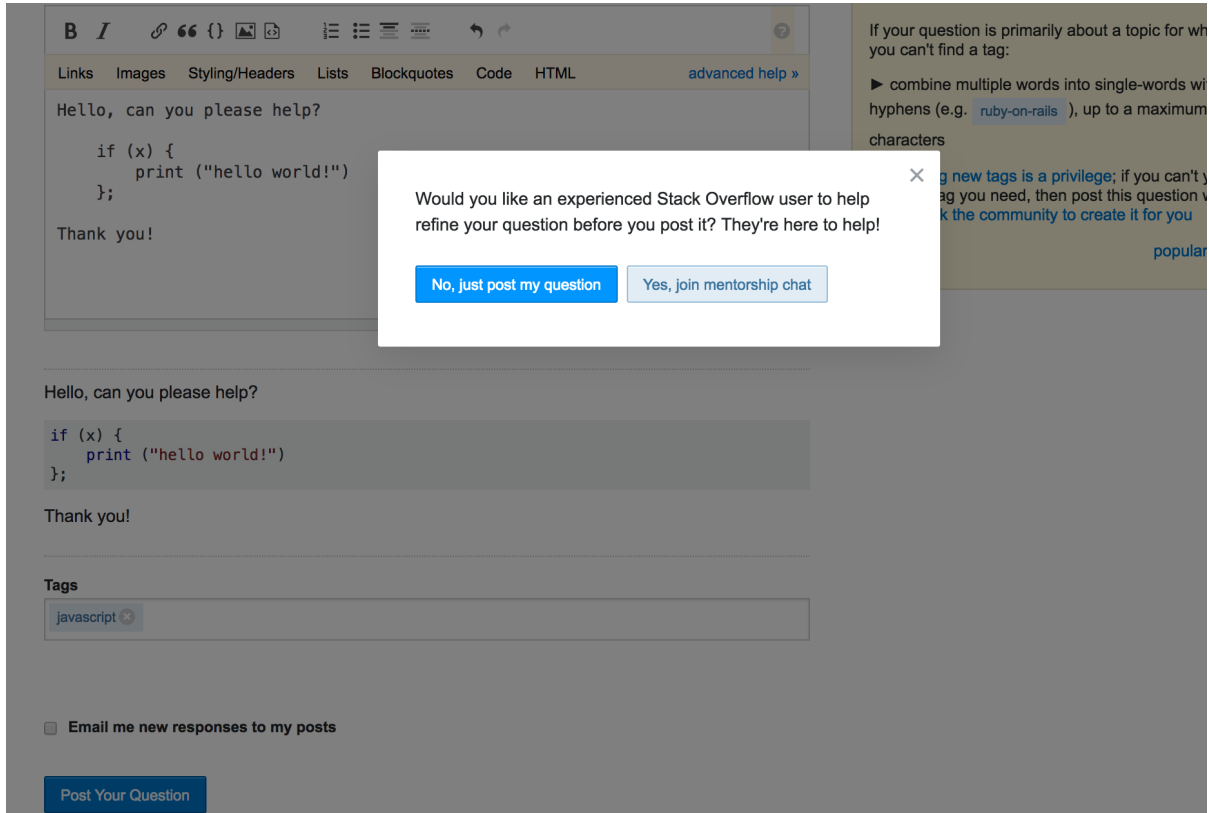
Figure 7.2 Eligible novices are presented with two options after selecting the `[Post Your Question]` button.

7.3.3.2 Help Room

As Mason enters the help room, the question he wrote is copied over into a new collaborative draft. He is greeted by an automated message and briefed on what type of help he can expect from a mentor (Figure 7.3).

7.3.3.3 Private Mentor Room

In the private mentor room, a notification indicates that Mason entered a help room and provides an excerpt from his question. Issa, an available mentor, volunteers to help Mason and informs other available mentors before she joins the *Help Room* (Figure 7.4).

7.3.3.4 Collaborative Editing of Questions

Issa then joins the *Help Room*, introduces herself, and reads through Mason's draft (Figure 7.3). After reading through the draft, Issa explains the issues with his question and suggests a couple
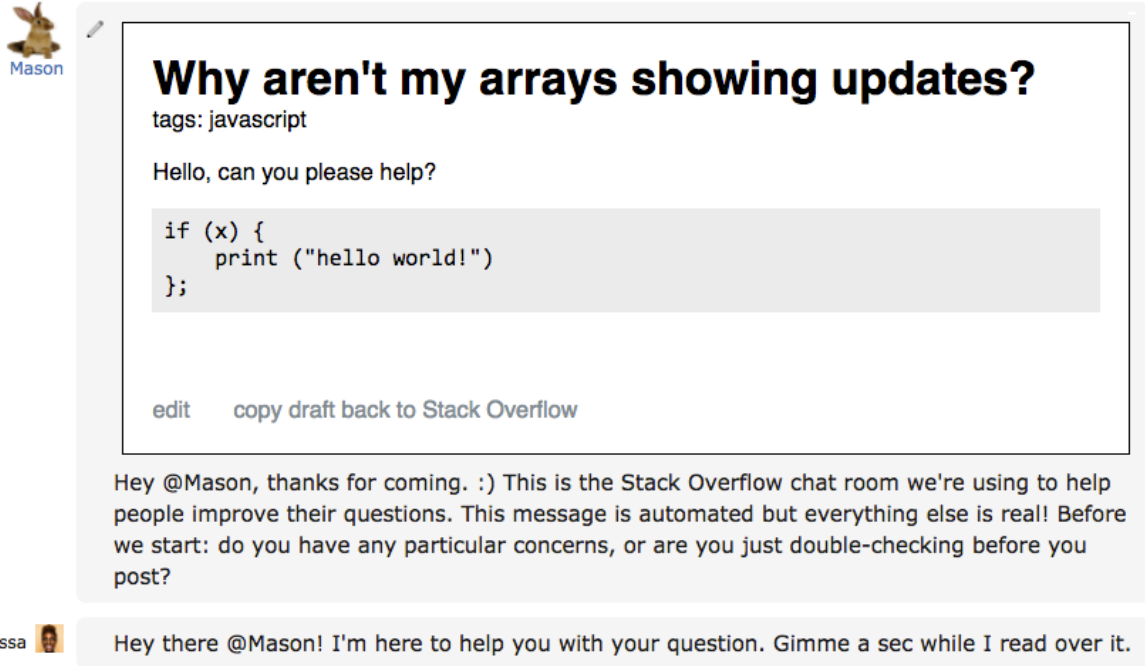
Figure 7.3 As the novice enters the mentorship chat, they are greeted and prompted for information about their question.

of changes that might increase the response rate to his question. Issa advises Mason:

To make your question better, you should probably add the 'arrays' tag, glad you have arrays in your title, format your code snippet, and tell us what you tried. Oh yeah and you should also remove 'thank you' from your draft. We don't do that here ;)

Mason considers Issa's advice and edits the draft.

Issa reads over the `[edited post draft]` to review Mason's updated question. Satisfied with the changes, Issa confirms that the question has improved and is ready to be posted.

7.3.3.5 Mentor Reflection

After helping Mason, Issa returns to the *Private Mentor Room* and shares her experience. Other mentors exchange advice on how to improve her feedback process and discuss ways to handle similar situations.

7.4 Study Design

To determine if mentorship impacted engagement and question quality, I conducted a study in which novices received advice from mentors on how to improve their questions. Specifically, the

Figure 7.4 After novices elect to join the chat, mentors are notified in the *Private Mentor Room*. In this room, mentors collectively decide and select who will help the novice improve their question.

goals of are study are:

- To observe and measure changes in question quality

- To understand feedback provided by mentors

- To improve experience for new question askers

- To learn how to scale these benefits to the whole community

I considered several factors when designing this study: the context in which a potential novice is receiving the offer of mentorship, the amount of time it takes for the mentor and novice to connect, the mechanism through which the mentorship occurs, and mentor availability.

7.4.1 Participants and Recruitment

To find potential mentors, I posted a description of the project and my goals in the Meta community, a popular Stack Exchange website where users share thoughts and feedback about Stack Overflow. I included a form for interested users to sign up to be mentors. In the form, I

asked for any prior relevant experience, as well as their opinion on the best way to help new Stack Overflow users succeed. A total of 80 users signed up.

I reviewed the list of users and selected mentors based on their Stack Overflow reputation points and their open-ended responses. I removed applicants who provided off-topic or antagonistic answers. I also removed certain applicants based on feedback from Stack Overflow community moderators. Overall, I gathered 63 mentors, who I confirmed and coordinated with through email and the *Private Mentor Room*.

Novice participants self-selected into the mentorship chat after composing a question on Stack Overflow. I offered the option to join the mentorship chat to less than 25% of all eligible users. The precise mentor-to-novice ratio varied over time based on site traffic and mentor availability.

7.4.2 Protocol

I emailed details to mentors prior to the launch of the study, including time of launch and how the mentorship system functions. I encouraged mentors to use the "How to Ask" page when they were unclear on how to help a novice [81]. As this was a live feature on Stack Overflow, I offered mentors a contact email in the event of an emergency. I also briefed mentors on the goals of the study.

To ensure a respectful and beneficial experience, I developed guidelines for mentorship [38]. I encouraged mentors to add examples of ideal approaches when responding to novice questions and tips for how to suggest edits.

To guarantee mentor availability throughout the study, I divided mentors into three groups and assigned each a time frame to join the mentor room. I reminded mentors to only log in to the room if they were available to help, ensuring novices were not offered help when none was available.

To gauge novice satisfaction, I distributed a survey after their participation. The survey appeared as an on-site link from hours 2-24 after the novice first entered the chat. My survey included 5-point Likert-type questions about their level of comfort posting to the community, whether the help they received was useful, how likely they are to recommend it to other users, and if they would participate again in the future. I also asked novices an open question about improving their mentorship experience.

To understand the mentor perspective, I conducted 20-minute semi-structured interviews with mentors about their experience. My interview questions covered how useful they found participation in the *Help Room*, how comfortable they felt helping novices with questions, if they felt their advice impacted question quality, and how important it was to connect with fellow mentors throughout the study.

My study had a duration of 33 days, not including pre-study recruitment and logistics or post-study interviews and analysis. At the conclusion of the study, I debriefed and thanked mentors for their participation.

7.4.3   Data Collection

For analysis purposes, I exported relevant Stack Exchange log data from the Data Explorer [31]. I collected timestamps for events in which a user: 1) opens the Ask A Question page (whether or not they would actually be offered mentorship), 2) is presented the option to receive mentorship, 3) enters the *Help Room*, 4) and posts the question. For each question an eligible novice posted, I collected the score, number of comments on the question, and whether the question was closed.

I define each set of interactions between a mentor and novice to be a *conversation*. To review mentor-novice conversations, I exported transcripts from each *Help Room*, including: the novice's draft question, the time the novice entered the help room, and the number of times a novice edited their question. Transcripts also included the following data for each message in each room: user id, display name, message content, and timestamp.

As mentorship was inserted into the normal question-asking flow, some novices may have accidentally joined the room. I did not include in my analysis instances where novices entered the *Help Room* and did not interact with a mentor, or instances where the novice spent less than 5 minutes in the *Help Room*.

7.4.4   Analysis

I completed a tripartite analysis of: question quality via vote score, mentorship topics through open coding of interactions in *Help Rooms*, and participant satisfaction through interviews and surveys.

7.4.4.1   Question Quality

To determine if a change in quality occurred, I compare questions by mentored novices to those from eligible novices who chose not to receive help.

I then measure the quality distribution of mentored questions and compare this to non-mentored questions. I adopt the following methodology used by Stack Overflow to characterize question quality:

Good   questions with a positive vote count

Neutral   questions with a net neutral vote count

Bad   questions with a negative vote count

To identify statistically significant differences in question quality, I conducted a Pearson's Chi-squared test on the characterization of questions. I also performed a Welch two-sample t-test comparing the scores of eligible questions to mentored questions.

7.4.4.2 Mentor-Novice Interaction

To understand the breadth of interactions that occurred in the help room, my colleagues and I analyzed a random subset of 100 total conversations across all 4 *Help Room*s (19.2% of all conversations) using qualitative coding and thematic analysis.

The first two authors individually open coded a 20-conversation subset of the sample, and met to compare and discuss emerging themes. Each conversation had between 1 and 5 (all) themes present.

Once we agreed on code definitions, we individually coded an additional 10-question subset with the closed set of codes. After confirming that our coding was consistent, we individually coded the rest of the 100-question sample. Inter-rater reliability was good with over 80% agreement.

7.5 Results

By the end of the study, my *Help Room* option was presented to 71,068 eligible novices—520 entered the *Help Room* and 271 interacted with a mentor and went on to ask a question. My colleagues and I identified 343 conversations between novices and mentors; we sampled 100 of those conversations.

In the following subsections, I describe the findings from my analysis.

7.5.1 Mentored questions have higher quality.

Following Stack Overflow's question characterization framework, I found mentored questions had the following distribution: 25% good, 49% neutral, and 25% bad. Compared to my control questions: 18% good, 51% neutral, and 30% bad. I also observed a 50% increase in the mean question score for mentored questions.

I found a significant difference between the good, neutral, and bad characterizations of the mentored questions and those that were not mentored (χ^2 = 7.48, p = 0.023). I also found a significant difference in question score for mentored questions (t = 2.2, df = 275.4, p = 0.027).

7.5.2 Mentors suggest high-fidelity improvements.

My qualitative analysis uncovered several themes of assistance that mentors offered to novices in *Help Rooms*. Most themes relate to community expectations of straightforward, comprehensive

questions. Quotes in this section are from novice-mentor conversations: to distinguish between them, each quote is labeled with the *Help Room* letter and conversation number.

7.5.2.1   Question Phrasing

In my study, mentors frequently suggested paraphrasing of problems, spelling fixes, and grammar improvements, but they placed especially high importance on question titles:

> *More important though, is the title. Better change to something like "Publishing web application failed", and leave the full details to the question body.* (A67)

Mentors also focused on how a good title can increase visibility and convey professionalism:

> *That edit looks really good. You may want to capitalize the first word in your question title so that it looks more professional. It will be the first thing people see when they click your question.* (A7)

In addition to improving the title, mentors also suggested grammar and spelling changes. Some novices openly acknowledged their difficulty with English, the preferred language used in the community [7].

Although conversations about phrasing may seem minor, my data suggest that they make up a large portion of mentorship discussions.

7.5.2.2   Formatting Posts

To post a question on Stack Overflow, users must use Markdown, a formatting language. Code that is not formatted properly may appear as a difficult-to-parse jumble of text. Many novices expressed confusion with code formatting:

> Mentor: *It doesn't appear that you've changed the code formatting. Are you confused?*
> Novice: *yes, sorry, highlighted code, did ctrl-K but didn't see any changes.* (B15)

Some mentors took the time to fully explain Markdown. After resolving the issue, one mentor sympathized:

> *It's fine! I rather have a long discussion about improvement than seeing another frustrated new user.* (A62)

Novices were unable to embed images because they did not have the reputation points required. Mentors guided novices through workarounds:

> *As you say, because of you reputation, Stack Overflow won't allow you to add images. This is mainly to avoid spam and/or inappropriate content. However, I suggest the following: [omitted]. Then post the link to the image in your post.* (B12)

As shown, novices encountered many formatting-related challenges, but with mentorship were able to overcome them.

7.5.2.3 Community Triage

Questions are frequently closed on Stack Overflow for being off-topic or opinion-based, because they are outside the scope of questions appropriate for the site (as outlined by the community). Other sites exist in the Stack Exchange network to support questions that Stack Overflow does not. Mentors helped novices rephrase or redirect questions that were off-topic. One mentor informed a novice about topic requirements and suggested ways to rephrase the question:

> *Questions asking us to recommend or find a book, tool, software library, tutorial or other off-site resource are off-topic for Stack Overflow as they tend to attract opinionated answers and spam. Instead, describe the problem and what has been done so far to solve it.* (B62)

Mentors also discussed how homework questions are considered off-topic:

> *This is certainly homework (or a learning exercise). Regardless a question about how to do a completely new method, or a tutorial is off-topic by the rules of [SO].* (A7)

I found that this study was also able to filter out malicious questions. For example, one novice asked how to hack a WiFi password. The mentor let the novice know the question was inappropriate:

> *Your question is off topic here....We're not a hacking service.* (C72)

Mentors also helped novices find the appropriate community for their questions:

> *ok the fact is that on SO you can't ask for libs you would need to do that on another site [link] (with some [rules] that we can check if you like), instead if you like some code it would be really great if you tried something, do you have some code, do you have some post that you already checked?* (A30)

In short, novices benefited from guidance on which types of questions do and do not belong on Stack Overflow. Mentor advice eliminated clutter and redirected novices to more appropriate communities.

7.5.2.4 Question Framing

On Stack Overflow, the community expects questions to have proper context and structure. Mentors often recommended that novices add more content to their question to increase its likelihood of being answered. One mentor encouraged a novice to add "more meat" to their question:

> *If you like, and it might help provide some more meat around your question. Maybe you can provide some practical example around issue where you have a method that does some sort of action* (A5)

Mentors also referenced the "How To Ask" page and other resources to help novices form a minimal, complete, and verifiable example [81, 82]. One mentor explained how a novice should arrange their question:

> *you have a problem with code so we must create a [How to create a Minimal, Complete, and Verifiable example](https://stackoverflow.com/help/mcve). This basically means that you need to insert relevant code (and you have, perfect), you need to add errors if you get error, you need to add current output and expect output.* (D32)

Adding more content was not the golden solution to making an answerable question, as one novice realized:

> *ah I see. It does kind of scream "WALLS OF TEXT, DON'T READ ME."* (D1)

Mentors clarified that is important to be clear and concise when asking questions. One mentor also highlighted how important it was to communicate the core problem when posting a question:

> *There [are] tons of people out there that know the solution, but if you put to much stuff around the question (the core problem), they get confused about the other stuff, so the more you can bring it down to the core issue the better it is.* (B2)

Overall, mentors communicated that the recipe for a successful question must have several ingredients: clarity, demonstrated research of the problem, and context.

7.5.2.5 Community Culture of Asking

Stack Overflow, like all communities, has cultural expectations of its users. One such norm is to ask direct programming questions without any salutations or other extraneous information:

> *You can probably remove "Hello" and "Problem" from the top of the question. While it's good to be social, it's kind of just fluff on a Q&A site.* (D1)

Mentors also reiterated how community users often are opposed to expressing gratitude:

> *You also might want to edit out the "Thank you!" at the end. I know it seems polite, but people object to it on Stack Overflow.* (D5)

Thankful for the assistance, some novices reflected on previous bad experiences asking questions:

> *Ok thanks for you help. I hope this time people won't attack me.* (D62)

Stack Overflow's community has established that salutations and gratitude have no place within a programming question, and mentors clarified that to novices.

7.5.3 Participants are satisfied with their interactions

To understand satisfaction with the *Help Room*, I surveyed participating novices with a small banner on stackoverflow.com that appeared between hour 2 and hour 24 after they entered the *Help Room*. I received 26 survey responses from novices: their results are shown in Table 7.1.

Table 7.1 A summary of novice survey responses.

Likert Statement	Median
I feel that I am a part of the Stack Overflow community.	4
I feel more comfortable posting on Stack Overflow.	4
The help that I received from this program was useful to me.	5
I would recommend this program to other Stack Overflow users.	5
I would like to participate in this program again.	5

Open-ended survey responses included suggestions about the question-posting process and requests to make finding duplicate questions easier. Other responses mentioned that the support within the *Help Room* was heartening, despite an occasional chiding tone.

I interviewed 5 mentors: 3 via text-based chat and 2 via video chat. Mentor participants responded positively. They found participation in the study valuable, and expressed a desire to participate in future mentorship programs.

One mentor was excited to help novices have positive experiences in the future:

> *If we can get the [original poster] through the first question with a positive experience and they can see how this site really works then we should get more good questions which feeds in to having more good answers.* (M5)

At the same time, some mentors were less positive about their own mentorship ability. One participant described his lack of confidence:

> *With questions in domains I am not familiar with, I find it hard to figure out if their question is actually on topic or not.* (M3)

7.6 Discussion

Mentorship in social Q&A communities challenges the way users receive feedback and develop into active contributors. I discuss how the implications from my human-human mentorship study provided a template for scaling up mentorship in other communities.

7.6.1 Advantages of human-human guidance online

As computer-based aid systems become more common, human-human assistance becomes more valuable. My findings suggest that novices may be more willing to engage openly with *real* mentors. I found that some novices were surprised to know that mentors were not robots, but actual people. Some novices only participated after determining that their mentors were humans: *"yes are you real?..or robot?"* Though they received an automated message when they joined the room, novices were pleased to have a human guiding them through the process.

Another advantage to having human guidance throughout the mentorship process is overcoming language barriers. Although community users prefer English for asking questions, Stack Overflow users are from around the world, where English may not be widely spoken [77]. The ability to interpret programming questions from non-native English speakers in a respectful manner is an attribute that *human* mentors have. Human mentors provided what bots could not—the compassion to help with a potentially difficult-to-understand question, and the patience to work all the way through it. If I used chat bots, it is likely that the study would have been biased toward native English speakers and would have discouraged users of different linguistic backgrounds to participate.

Uniquely, human mentors were able to function as a sounding board for questions, sometimes inadvertently resolving them within the *Help Room* itself through the process of teasing out an appropriate question. Not only might this reduce the number of questions posted to the site, but may also provide novices another approach to thinking about their questions. If I had not focused on human mentorship, conversation may not have been as organic and prone to serendipitous resolutions. This also allowed us to have a better understanding of the range of conversations that may occur, so that I can scale up mentorship efforts based on the conversations mentors and novices engage in.

Finally, my involvement of existing community members in the process of socializing novices not only supports Kraut et al.'s design claim which states that involving old-timers in formal

mentorship can improve newcomers' commitment, but also gives those existing members more empathy towards the new user experience, and a vested interest in their success on the site [59].

7.6.2 Scaling up and out

"In order to scale, you have to do things that don't scale" [52]. I approached this study as a proof-of-concept of the collaborative drafting feature as an intervention to increase site engagement. In keeping this study at a small scale, I identified which features I wanted to employ, retain, and discard to further enhance the onboarding experience for novices. For example, the Mentorship FAQ document was one promising aspect of my study [38]. Authors and mentors iteratively added to a collection of experiences and observations about how they evolved their advising strategies. Another example is how mentors decided which mentor should help each novice: based on availability, and on initial content of the question. This helped us determine that novices should only enter the *Help Room* once they had completed a draft, instead of while writing it.

In order to provide support to all novices who want it, I would need to scale up mentor recruitment, training, and availability. Taking advantage of the large scale that many online communities enjoy, broadening mentor recruitment to any existing community members who possess certain characteristics or meet certain criteria is straightforward. For example, on Stack Overflow, any members with a certain reputation level may qualify to mentor novices. In addition, as mentored novices continue to acclimate to the site and transition into expert contributors, I could recruit them to be mentors themselves. These newly-minted experts would be able to see the value of participating in the *Help Room*, be more likely to volunteer their services, and possibly be more sympathetic to novices, as they were recently in the same position.

Scaling mentorship documentation and training requires both formalizing organic FAQs as well as providing a mechanism to ensure compliance. This could be both self-motivated and community-policed. Maintaining a *Private Mentor Room* for mentors to assist and encourage each other is critical.

Finally, scaling up should include around-the-clock mentor availability. For example, I could automate a mentor selection system that designates time frames in which mentors could help. In this way, the same mentor would not be obligated to be online to help all the time. To reinforce this mechanism, I could offer reputation points and badges to mentors that aid novices during their designated time frames. Expanded mentor availability could also come naturally through expanded recruitment.

Although this study was conducted within a specific community, my findings provide inspiration for how to scale outside Stack Overflow and into the workplace. An example of this is to incorporate collaborative drafting into new employee training. New employees could be mentored by senior employees on how to use internal tools. This could help new employees get

acclimated to company culture faster and also serve as a great team-building exercise.

7.6.3 Implications for community-based mentorship

I discuss implications I discovered in designing for community-based mentorship and make design recommendations to guide researchers and designers of similar systems.

7.6.3.1 Check in with existing community members

I encountered opposition and skepticism from the Stack Overflow community in response to my *Help Room* proposal. For example, some users believed that novices would take advantage of the system: *"the biggest concern I see is that new users coming for help will see these volunteer users as people to directly answer their questions."* As Kraut et al. outline, existing group members are distrustful of newcomers [59]. I also, however, received valuable feedback and suggestions concerning technical implementation, including suggestions for how to best implement the collaborative editing feature. Ultimately, involving the existing community early and continuously in the design process was a critical step in changing the nature of the community, and involving existing community members was a critical piece of scaffolding in creating a system more friendly to novices. Any designer considering implementing a new mentorship system—especially for communities with a strong old-timer culture (like Wikipedia editors)—should get existing community members involved in early design stages, both to mitigate opposition and to receive useful feedback and support.

7.6.3.2 Reduce visibility of non-participants

Making *Help Rooms* accessible to any mentor at any point, even when they were not actively mentoring, created situations in which there were many non-participants quietly observing a conversation. The chat interface on Stack Overflow also shows participant avatars in the sidebar and animates them in and out as they join and leave. Not only did this create confusion about which mentors were available and currently assisting novices, but it may have made novices more reserved about asking for feedback about their questions, as Kraut et al. suggest (people are more willing to contribute when an online group is smaller) [59]. Reducing the visibility of non-participants in a mentorship chat room may help to reduce apprehension. When creating new mentorship functionality, consider making observers hidden or less prominent. When adapting existing infrastructure, reduce room membership's visual prominence, or focus on participants. For example, if a high-traffic site like Quora were to implement mentorship, removing obvious indicators of scale (like precise numbers of votes) might be prudent.

7.6.3.3 Create mechanisms to track and reward progress

In my study, mentors had no simple way to track the progress of the novices that they helped. Many of them cared deeply about how the novices they helped were progressing. They frequently linked back to novice account profiles and questions in the *Private Mentor Room*. Providing a simple means by which mentors can monitor the results of their labor, as well as a reward mechanism for helping novices, would fit well into communities with established reward frameworks, supporting intrinsic motivations and creating extrinsic ones [59]. It could also help integrate mentorship functionality into the community more broadly, and to monitor longitudinal gains from *Help Room* participation. Reddit, for example, has a built-in reward mechanism in the form of karma, which offers opportunities for both tracking impact and motivating participation in a mentorship program. It also has flair, which shows an on-site badge next to a user's name based on any kind of self-described or site-designated characteristic. This is another mechanism that can be used for tracking and rewarding participation.

7.6.3.4 Mentor many-to-many, one-to-many, and one-to-one

Allowing mentors to help novices based on their own accord and availability created situations where: many mentors helped many novices with no assignment, one mentor helped many novices, and one mentor helped one novice. It may be the case that different styles of mentorship are more appropriate for different novices and different needs. For example, simple issues with question phrasing may be appropriate in a many-to-many scenario, while questions that need significant improvement might need one-to-one guidance. Implementing both group *and* individual *Help Rooms* could better support different needs and communication styles. The specific kinds of issues and needs anticipated should be considered when creating a new mentorship system.

7.6.3.5 Integrate mentorship functionality precisely when needed

The *Help Rooms* on Stack Overflow were designed to be available to novices just in time. That is, novices have the opportunity to receive assistance and guidance when they need it most: when they're asking a question. Existing guidance in the form of FAQs and help documents (collective socialization) does give novices information that they need, but not when they need it [59]. Optimizing mentorship entry point placement such that it is available at the appropriate time may increase its utilization and usefulness. Any site or community where the primary focus is its own members' contributions should place their mentorship feature within that contribution system. For example, Twitch, a game-streaming platform, could include the option for mentorship or support when a novice begins their first stream.

7.7 Related Work

My work is related to other work in two key areas: participation in online communities and peer-driven approaches for helping engagement.

7.7.1 Interventions to increase participation

Large online communities have the challenge of inadvertently excluding some users from participating, but few have challenged themselves to be more inclusive. Discussion-based Q&A, such as Quora, have attempted to be more inclusive through language and support discussion forums for Spanish speakers [22]. Even Reddit, the "front page of the internet," has modified their home page to be more inclusive of lurkers and new users in order to disseminate more diverse content and increase participation [95]. On the open-source frontier, GitHub, a collaborative code-hosting platform, implemented a first-time contributor badge to help community users be more mindful of new users acclimating to site norms. Keeney, the lead engineering manager of the new feature, claims that, *"one of the best ways to grow your community is to welcome new contributors [58]."* My work follows the same compass, but through mentoring.

7.7.2 Iterative feedback in mentoring

Mentoring has demonstrated to be most effective through iterative feedback. For example, the frequency and swiftness of feedback from a mentor can directly affect productivity [2]. In addition, Kulkarni et al. explored rapid peer feedback with Peer Studio, a system that allows students to share writing assignment drafts with other students [60]. While I also focus on an iterative draft-based method for delivering feedback, I do not focus on peer relationships. I explore iterative feedback through a mentor-novice relationship in order to help novices gain insight from the perspective of more experienced users. Finally, Peer Studio's feedback mechanism is predetermined and closed-ended, while I focused on conversation-driven, open-ended feedback in a live online community.

7.7.3 Dialogue-supplemented learning

Visualizations can also serve as a great tool for mentorship. For example, Codechella, a chat built upon a code visualization and collaborative learning platform, demonstrated that novices gained knowledge and showed affective exchanges such as encouragement and banter [49]. My work is distinctly different from Codechella as I do not allow mentors to edit content directly, but to guide novices through the experience. Thus, facilitating mentors to explain suggestions to novices and not doing the work for them, which is likely to occur when experts lead the discussion.

Another dialogue-supplemented, collaborative platform is the Notes feature of OpenStreetMap (OSM), "the Wikipedia of Maps [85]." Similar to OSM, new users tend to rush to the socio-technical community when they are in need yet the vast majority of contributions come from previous users. Unlike OSM where there is often a natural disaster with a high risk of death that encourages users to contribute, new users post to Stack Overflow to resolve their high and low risk errors when writing code. However, unlike the legitimate peripheral participation of the OSM's Notes feature which can be used to asynchronously report issues within the platform [85], my collaborative drafting feature expands the resources of users to get synchronous help with content to be posted in the community.

7.7.4   Organic mentor-novice relationships

Informal and long-term mentorship is also likely to occur in online communities. Evans et al. investigated websites for writing fan-fiction as fora for distributed mentoring, focusing specifically on informal mentorship in story comments [30]. Informal mentorship allow for a more natural environment of help to emerge. I created a similar occurrence as mentors voluntarily selected which novices to help. Moreover, Trainer et al. studied long-term online mentor-novice relationships based around specific coding projects [109]. In contrast, I focus on learning how to scale real-time mentorship for novice contributors in a large programming community.

7.8   Limitations

Help Room limitations. By extending the existing chat room feature to support our mentor-ship program, I introduced trade-offs in our design and the reporting of our study. My chat is not perfectly designed for multiple simultaneous conversations. It lacked the ability to easily distinguish between separate conversations, which resulted in novices being confused about suggestions that may have been for their draft or for another novice's draft. This also made it challenging to determine when conversations may have ended between a mentor and novice.

Different styles of mentoring. The types of feedback a mentor provides can vary in style and effectiveness. As a result, some novices may have received more help than others. I introduced several measures to help control for mentorship style: allowing coordination in the *Private Mentor Room*, creating a FAQ [38], and providing active feedback to mentors. However, I do not know how effective these measures were in controlling style.

Self-selection bias. Self-selection bias may manifest in my study due to mentors and novices volunteering to participate in mentorship. Consequently, the types of users that post on Stack Overflow may have an effect on the feedback received, the interactions with mentors, and the question quality. As a result, my analysis may not identify all types of feedback. Further,

novices that elected to get help may be more likely to create high-quality questions. However, my manual inspection of question drafts before mentor feedback found problems that are typically associated with unanswered questions [5].

Generalizablity. There are several factors that may limit the contexts in which my technique can be applied. In my study, mentors knew that the study was finite, therefore they may have been more amenable to actively participating for a short period than they would be for a longer period. This may affect this technique's scalability if deployed permanently. In addition, the negative comments that novices fear receiving on Stack Overflow may not exist to the same extent in other forums. Hence, there may be different types of advice that mentors offer in other non-programming communities.

7.9   Conclusion

In this chapter, I applied theory related to learning and communities of practice to a social Q&A site, by using methods related to mutual engagement and formative feedback. I created *Help Rooms* in order to provide timely and formative feedback to novices about their questions before they post them. I also used those *Help Rooms* to study the utility of collaborative question drafts. To understand the effectiveness of my technique and the types of interactions it facilitated, I performed a one-month live study on Stack Overflow.

My findings suggest that the quality of mentored novice questions is significantly different than that of questions that were not mentored. Specifically, I found that mentors provided feedback that improved the question quality by: annotating each question with important information, including crucial context details, explaining attempted solutions, and adopting a tone that meets community standards. As a result, the average scores increased over 50%, and novices were extremely satisfied with their mentorship experience. Further, I discuss how this study can expand to other communities through user insight before building and taking advantage of the flexibility of human mentors.

In summary, my mentorship program improved the onboarding experience for novices and enabled mentors to improve their feedback skills. By involving users in making their own community more empathetic and supportive, I pave the way for a more engaged future generation of novices.

In the next chapter, I understand how identity-based signals can be utilized to influence participation in sub-communities. I investigate how barriers to participation can be influenced by identifiable peers in a small, private sub-community situated within a large, public online programming community.

CHAPTER

8

SUB-COMMUNITY INFLUENCE OF BARRIERS

As more people learn to code and enter careers in software development [62], more software developers will likely be faced with a double-edged sword of how to contribute to Stack Overflow. One advantage of their expertise is that they have a range of experiences and can be equipped to answer more questions. The disadvantage here is that they will have to find a way to offer a solution without giving an example related to the "secret sauce" of their affiliate organization. This leaves developers with one question: *How do you ask or answer a proprietary question [117]?* More specifically, how do we create a community where users can ask a specific, high-quality questions and in turn receive specific, high-quality answers?

In this chapter, I investigate how barriers (Chapter 4) shift within sub-communities.[1] This work builds on the approaches demonstrating that sub-communities can reduce the fear of engaging and increase a sense of belonging [14, 71]. I crafted a study investigating how a Q&A sub-community can decrease the perception of barriers, such as a discomfort among strangers and an intimidatingly large community size, to contribution. To investigate how these barriers can be reduced, I created a private Stack Overflow Team and designed a study to understand how creating a sub-community on the popular platform can dismantle barriers to participation. I

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[1]Significant portions of this chapter are in submission as D. Ford and C. Parnin, "Fast, Relevant, and Familiar Feedback: How Stack Overflow Sub-Communities Influence Barriers to Participation" at *(IEEE/ACM Conferences*
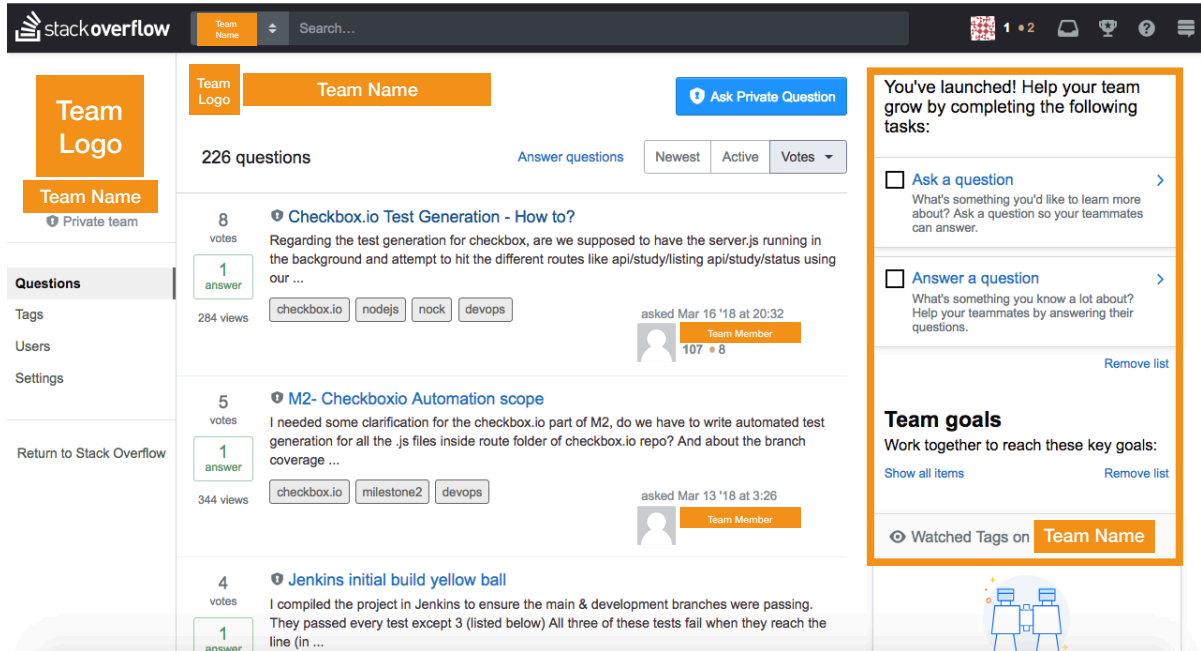
Figure 8.1 A private Stack Overflow Team instance places an emphasis on all users contributing to the teams growth by asking and answering questions.

immersed 111 software developers in a Stack Overflow Team instance while they worked on their software projects for 4 months and studied their activity. To understand how this experience influenced the perception of barriers, I conducted interviews and distributed surveys. Specifically, I find that:

- While most developers did not ask questions, their perception of these barriers inhibiting their participation was influenced.

- Participating in an intimate, specialized community allowed for more opportunities to contribute.

- Having an offline relationship with online community members increased trust and belonging to the Stack Overflow community.

These findings help us build an empirical-based understanding of how I can influence participation in large Q&A platforms.

8.1 Motivating Example

To be concrete about how some people hesitate to post on Stack Overflow, consider Mali's recent experience posting to Stack Overflow. Mali is a software developer at Facebook. She is working on an her Facebook internal project when she encounters a bug in her code. Like many software developers, she turns to Stack Overflow to interpret what the specific error means. She doesn't find a question that matches her's so she decides to post a question. With the consistent flow of Facebook making headlines regarding internal code and algorithms leak Mali decides to be very cautious of how her question may be linked back to her company. Thoughtfully, she creates a new anonymized Stack Overflow account to post her question. Before she posts her question, Mali scans the code snippet she attached to her question to ensure she redacted all proprietary information. Moments after Mali posts her questions, she receives comments from a user:*"Can you post the remaining code snippet? I don't quite understand what your endgame is here with this limited context."* This puts Mali in a bind: she can't risk posting proprietary information. If she were to post any additional code she would have to redact so much code that the question will now be too general and not match the specific problem she encountered. She weighs her options of either remaining stalled on this question for a while or risk posting proprietary information online and violating the terms of her employment. Ultimately, Mali decides the safest option is to delete her question from Stack Overflow.

Mali's interactions on Stack Overflow tell us a lot about the process that even experienced software developers face when seeking answers to their very specific coding problem. The process of extracting proprietary information from the question is: 1) quite time consuming, and 2) will likely not result in a successful solution that could be adapted the initial problem. While these challenges sound negligible, they can be quite insurmountable and be strong inhibitors for those who want to contribute to Stack Overflow.

8.2 Background

To understand how sub-communities can decrease the perception of barriers, I created an instance of a Stack Overflow Team. Stack Overflow Teams is "a private, secure home for your team's questions and answers [83]". I selected to use Stack Overflow Teams for our study because I wanted to situate our sub-community within a broader community that participants would be familiar with.

Stack Overflow Teams also offers an extension to mechanisms afforded on the broader Stack Overflow platform. For example, voting has different constraints. On the Stack Overflow platform a user must have 15 reputation points to upvote and 125 reputation points to downvote a post. However, in the sub-community users can upvote without the gated reputation permission, but

still need 125 points to downvote as shown in Figure 8.2. In this figure, the community member is encouraged to reach out to the original poster and offer "a constructive comment or edit." This interaction is different from the notification that appears when members select to downvote (see Figure 8.2). The sub-community instance encourages members to amplify content that they have found most useful and encourages that less helpful post be proposed for revision. As also indicated in Figure 8.1, this sub-community places an explicit emphasis on Stack Overflow serving as a growing archived forum and wiki for it's members.

Similar to the badge awarding recognition available to the broader Stack Overflow community, members of the sub-community can acquire them specific to the community. Another advantage to us is that members can easily switch perspectives from the sub-community to the broader community within the same site—both are connected through a common user id. This private sub-community can also serve as a staging area where members can feel more comfortable contributing and be rewarded for that activity. Thus, feeling empowered to engage in the broader public community.

> Thanks for the feedback! Votes cast by those with less than 125 reputation are recorded, but do not change the publicly displayed post score.   ✕

(a) Public Stack Overflow

> You need 125 reputation to downvote a post. Let <Participant Name> know how their post can be improved by adding a constructive comment or edit.   ✕

(b) Sub-Community Stack Overflow
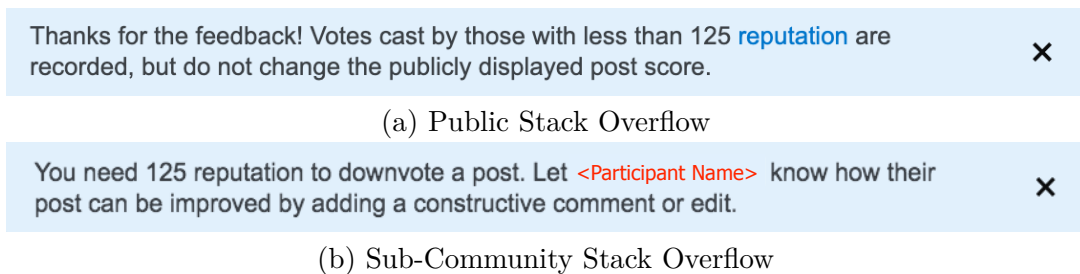
Figure 8.2 Downvoting on Stack Overflow requires 125 reputation points. However, the private sub-community invites the downvoting member to give constructive feedback to the poster.

8.3   Methodology

8.3.1   Research Questions

I investigate the following research questions:

RQ1: How do lurking community members feel about joining a sub-community?

Common reason people lurk are because 1) they cannot identify the opportunity to contribute and 2) they are satisfied with their mode of interaction [90]. How does that perspective shift if invited to engage in a sub-community?

RQ2: How can participating in a private technical sub-community change member activity?

Prior research demonstrates that sub-communities can provide lurking members with a staging platform and allow for community exploration [74]. I want to investigate if giving lurkers the opportunity to increase their community membership will change their participation in any way.

RQ3: How can the opportunity to engage in a new technical Q&A community influence member motivation?

In studying group with low interaction, changes in overt action offer only a coarse-grained understanding of an experience [122]. In analyzing the change in attitudes and perception of motivations, I aim to create more comprehensive interpretation of true engagement.

8.3.2 Study Design

Protocol. To answer our research questions about the effects of private Q&A setting, I created a local instance of Stack Overflow Team. I immersed participants in the Stack Overflow Team for 4 months. Participants were instructed to use the the Stack Overflow Team the same way they use Stack Overflow Public: to ask questions and answer questions about their technical work. Once participants were identified I invited them to register for the Stack Overflow Team using their provided email address. Once registered participants can switch between Stack Overflow Public and Stack Overflow Team account as they see fit. To collect data on their Stack Overflow experience, I distributed a pre and post survey to participants at the beginning and end of the study.

Participants. I immersed 111 participants from an Undergraduate Software Engineering course at a university into a private team on Stack Overflow for 4 months. I chose to use students from this course since it has a semester-long course project centered around industrial software development in health care. The rigor, practicality, and duration of this course provided a controlled private context for understanding an Stack Overflow Team. Participants were not monetarily compensated for their participation.

Pre-Survey. In the pre-survey, I asked participants about how they use Stack Overflow Public and Stack Overflow Team prior to the course. I asked participants to list their top 3 advantages and motivations to using Stack Overflow and why they think they may use Stack Overflow Team any differently than Stack Overflow Public. I also asked participants to rate the degree that specific barriers stop them from contributing to Stack Overflow and if there are any additional barriers that I did not list. I included all 5 Stack Overflow barriers that had a significant difference between men and women as reported by Ford et al. and 2 that research proposed

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that may be reduced in a private setting [41]: *Qualifications*, *Perception of Slacking*, *Lack Of Awareness*, *Intimidating Community Size*, *Stranger Discomfort*, *Onboarding Hoops*, and *Fear of Negative Feedback*. These 7 barriers also cover the three categories of inhibited online community participation.

Interviews. I randomly selected low-activity participants throughout the 4 months participants engaged in the sub-community. Specifically, those who had not asked questions and interviewed them about their lack of participation. All interviews were conducted over a text-based chat and lasted less than 15 minutes. First, I introduced ourselves and I asked each participant one question: *I noticed your activity has been low. I'm curious, what's holding you back from posting?* In this interview participants were allowed to give as long or as short of an answer as they desired.

Post Survey. In the post survey, I asked participants how they used Stack Overflow Public and Stack Overflow Team over that time period. I also asked them about the same barriers asked in the pre-survey, specific advantages or motivations to using Stack Overflow Team. I asked them how and why they may have used the Stack Overflow Team differently than Stack Overflow Public. I also collected their private and public Stack Overflow account id for analysis of interactions between both.

8.4   Analysis

To answer RQ1, my colleagues and I analyzed open responses about participant's prior experiences using Stack Overflow. We reviewed responses and conducted an interpretative phenomenological analysis of barriers [97].

To answer RQ2, I conducted a statistical analysis on participant's activity before and after engaging in the Stack Overflow Team. I measured differences in participants score in both versions of the community. I conducted a Wilcoxon Signed Rank Test for significance on ratings of barriers. To identify if participants were more inclined to post in one community over the other, I also studied the number of questions and answers a participant posted in both the public and private communities.

To answer RQ3, I analyzed the motivation and advantages of participants reported in the post survey. To unpack descriptions of motivations and advantages across both public and private settings, my colleagues and I used a grounded theory [104] approach to analyze responses. We used Atlas.TI [6] data analysis software to qualitatively perform multi-phase coding. First, we conducted first-cycle descriptive coding on open responses to describe the context of each comment. In the second phase, we performed axial coding to recognize core phenomenon and relate interviewer interpretations to criteria.

Table 8.1 Overall Participant Activity

Participation Level[1]	Activity Type[2]	Count[3]
Low	Posted 0 Question `AND` 0 Answer	43
Medium	Posted 1 Question `OR` 1 Answer	7
	Posted 0 Question `AND` >1 Answer	0
High	Posted >1 Question `OR` >1 Answer	25
	Posted >1 Question `AND` 0 Answer	15
	Posted >1 Question `AND` >1 Answer	3

[1] Participation levels are split identify the distinct forms of participation regarding posting a question or an answer [2] Each participation level has multiple levels. Voting was not taken into consideration for these values [3] Counts are out of the 83 participants who completed both the pre and post survey. Values do not sum to 83.

8.5 Results

All participants were familiar with Stack Overflow prior to this study, but only 82% reported actively using their Stack Overflow Team account. All participants were university students and 12% identified as a part time developers. 80% of the participants identified as men, 12% as women, <1% as non-binary, and 6% preferred not disclose their gender. Of the 111 participants in the course only 83 completed both the pre and post survey. By the end of study 38 of the users went on to ask a question and 13 to answer a question. Table 8.1 demonstrates the breakdown of how participants engaged. For our brief interviews, 8 out of 13 participants I selected responded with reasons for not posting. I report their responses as evidence for barriers that may persist in this private community. Each quote in this section is accompanied by each participant's Stack Overflow Team ID.

8.5.1 RQ1: How do lurking community members feel about joining a subcommunity?

Great Expectations. From our pre-survey, I find that some participants had initially high hopes of what Stack Overflow Team would be and expressed enthusiasm in the ability to have a version of the helpful community they previously spent lurking in before. Participants thought using Stack Overflow Team will help them feel more qualified to answer questions. One participant acknowledges an opportunity to answer more simple questions:

I'll probably post and respond more on the private page, since it's with students,

who are all trying to figure out a common idea, and with TAs and professors who are trying to teach and help without that (in theory) condescension for easy and simpler questions. (P86)

Participants expressed the it was important to trust where their answer to questions were coming from:

Yes, since it has only [TEAM NAME] students it will be more reliable and trustworthy. (P143)

I may post more questions on the private team as I feel that getting an accurate response is more likely there than on the public site. (P124)

As expected, some participants expressed that the relevance to work contributed to their interest:

Yes. I plan on being much more active on the private team site because the questions/answers are all extremely relevant to my work. (P165)

From participant responses, I find that participants anticipated the private team can be a safe space where they can have more opportunities to help their peers. These findings correlate with findings from Ford et al. that lurkers want to contribute but face challenges identifying opportunities to add value to the community, including novices and other lurking members [41, 101].

Barriers Persist. To understand how barriers may have plagued some participants during the study, I interviewed 8 participants. I find that participants were hindered by both social and cognitive barriers.

One participant acknowledged their challenges with feeling they should be able to find a solution without depending on the help of others:

I haven't made any SO posts mostly because I feel like I should be able to solve the problems on my own. For the issues I'm really stuck on, trying to draft a SO post that would "make sense" seems difficult. (P175)

Another participant mentioned how they were frustrated by other participants linking to other content as opposed to sharing the code snippets:

Something that often blocks me from being able to help is a lack of code snippets/error messages provided in the questions asked by my peers. Often they'll say "here's a link to my repository," but as a student I can't view it. It would be better if the student provided small snippets of the error message and the possible issue in their code. (P121)

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While some were blocked by responding how people shared content, others had challenges finding opportunities to post at all. One participant mentions how all the questions have been asked or answered already:

> *I haven't posted yet because I start on projects late enough that so far all of my questions have already been asked and/or answered.* (P95)

Similar to other software development settings, participants were able to build relationships in offline and other online mediums. Interview participants responded that their question was often better suited for those mediums where they are targeted at one person:

> *Nothing really holding me back right now I just have not had any questions that I feel would be good for stack overflow. Most of my questions I had have been answered through slack (by teammates or TA) or in lab.* (P85)

Another participant goes on to mention how they only needed to use the sub-community during the initial environment set up. After that point, they found it was easier to ask in a smaller sub-community:

> *Well I posted when I needed help setting up at the beginning of the course but after that I've been able to figure things out on my own or by asking my teammates.* (P123)

Other interview participants have noted that they have not felt the need to post since others are asking and answering. A few participants also acknowledge how Slack, another resource used in the course, has been a secondary avenue for communication. I find that barriers participants identified during the study are consistent with barriers that community members have described in prior literature.

8.5.2 RQ2: How can participating in a private technical sub-community change member activity?

I find that participants felt more comfortable asking for help in a private environment. I find that some participants who may have been more quiet in the course found Stack Overflow Team to be a place where they can feel more comfortable answering peoples questions. I did not analyze any differences between votes and edits as only the teaching staff used those forms of interaction. One reason for this could be due to the *Awareness of Features* barrier—users are not familiar with the value to their experience of using these mechanisms.

From our survey results, I analyzed both survey responses of 40 participants who posted in the Stack Overflow Team. Figure 8.3 demonstrates the perception of barriers have changed across those at the beginning and end of the study. Specifically, I identified a statistically significant difference in the *Perception of Slacking* barrier (p = .046, α=.05).
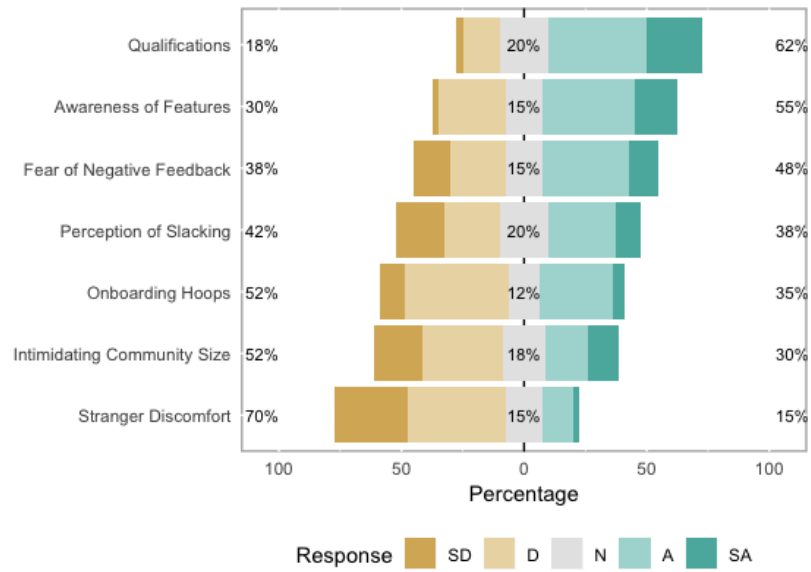
(a) Pre Survey
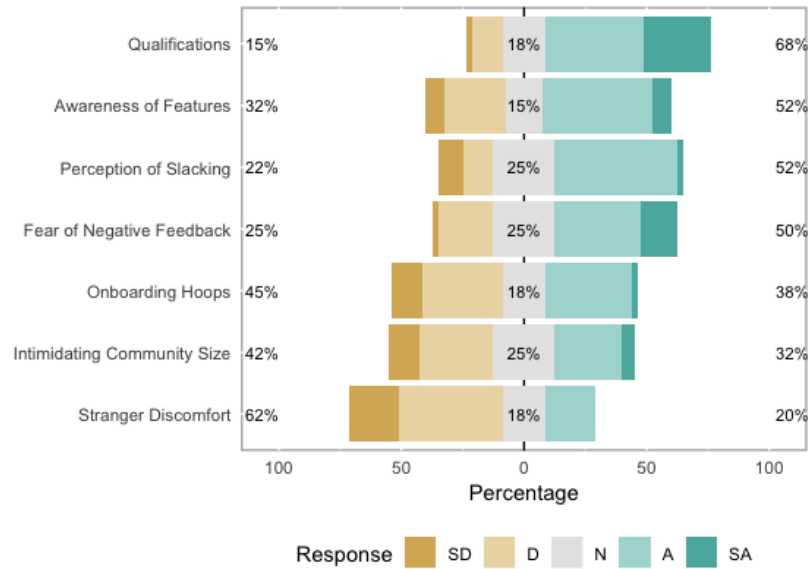
(b) Post Survey

Figure 8.3 Pre and Post survey results of participants that either posted or commented.

8.5.3 RQ3: How can the opportunity to engage in a new technical Q&A community influence member motivation?

After participating in the private Stack Overflow Team participants reported advantages to participating relating to the type of content they were able contribute. We identified seventeen codes from our analysis which we resolved into the four themes I describe below.

Archived Documentation. Participants went on to acknowledge how they began to see Stack Overflow Team now as an archive where documentation is kept.

Specifically, participants were happy to have a single point of reference that is archived and accessible:

> *Finding answers to questions on one location, having an archive of questions, and pointing people to answers to questions.* (P120)

Similar to Caulfield's choral explanations[20], participants found the having a variety of solutions to a questions was a significant advantage of the Stack Overflow Team:

> *Multiple people respond, so different solutions can be provided.* (P128)

Participants acknowledge that as this archive of choral explanations continues to grow, the answers will become increasingly useful:

> *There is a written history of previous issues, making it increasingly useful the longer it exists.* (P125)

Speed and Opportunity. Participants also acknowledged the speed at which community members responded as an advantage to using the community. One participant acknowledge the comfort in knowing that there will always be someone to answer the question:

> *Usually there is someone active, so any questions can get answered relatively soon.* (P145)

To be as concrete as P124, the speed of the community allowed for, *Faster bug fixes when one team member has a question.* In the event that a bug solution was not yet available it allowed for participants to stay update-to-date. One participant acknowledge how it was helpful to log work-arounds:

> *Having a finger on the pulse of the typical problems that are occurring.* (P194)

Bespoke Problems and Solutions. The most prevalent response participants had about using Stack Overflow Team is the advantage of having a space that felt more comfortable and bespoke to their experience:

There is a sense of community that is not present in the public stack overflow. You are more likely to receive feedback relevant to your goals. (P125)

Even further, some participants outlined why having a private space was important to them:

1. The question/answers are specific to the common environments used by the team. 2. Referrals to outside sources will tend to be more relevant 3. More trusted answers. (P155)

Participants mentioned that one benefit to working in a private space is that contributors can post a specific bug or issue they came across purely in hopes that it may help someone else:

If the team is working on the same project it means someone else might have ran through the same issue and already know the answers. Or someone might run into the issue and there would be a Q/A about it. (P143)

In addition to finally now being able to leave source code, now without the fear of sharing proprietary information, contributors can post in-depth solutions:

In-depth solutions with code showing the step-by-step. (P145)

By the same token, some participants found this to increase the likelihood that they will find an answer that matches their specific problem–especially an answer that works:

Often times, teams share similar project and has context around it, so they understand the questions better. There is a high chance of finding answers for the questions I have. (P168)

Familiar Feedback. Participants mentioned how they felt more comfortable receiving the feedback from this Stack Overflow Team for several reasons. One reason participants explained was finding solace in the idea that other observing community members had a similar base knowledge:

Get answers to my questions, be in a group with people who have similar questions, be more comfortable with the people I am interacting with. (P117)

Another reason participants mentioned contributed as an advantage of the community is that they had the opportunity to build these relationships in offline communities prior to joining the study:

Narrows the community to those who know about the same project, there is less intimidation from the large community of users, and it is people I have interacted with in real life for the most part. (P112)

Interacting consistently with the same users offline and online allows for bonds to form so that participants can feel more comfortable asking questions. Knowing that all Stack Overflow Team community members were "real" people offline allowed for participants to reduce the barriers of community expectations and increase the perception of trust:

> *It is a smaller community with less expectations. Often, the people responding are more familiar with the technology or project that is being worked on. Your questions do not get posted to the global web and thus can contain more sensitive details about your issue, rather than having to obfuscate things that may compromise the integrity of your software.* (P97)

In summary, the main advantage of this sub-community was that participant's had access to: *"Fast, relevant, and familiar feedback."* (P134)

8.6 Discussion

Interpreting Meaningful Interactions. Our study demonstrated that sub-communities provide opportunities for community members of a varying activity range to have meaningful interactions. Albeit that more than half of our participants (51%) did not post a question or answer in the sub-community, an attitude towards the presence of barriers was reduced. Comparatively, participants reflected that not only did they feel as though they were a part of a more intimate community, but that they now had the ability to build to make it work for them. One example of this is the emphasis on building a corpora of confidential how-to's, facts, and guidelines for the specialized community and having the ability to give rank to the material: "*[I] can vote for the best answers so it is easy to see which answer is actually the most effective/correct* (P109). It is important to note that voting is a mechanism that these same members of the public community already have access to, however the ability for it to dictate a more meaningful interaction is what engaged members. This implies that the clutter reduction of other members and posts provided the opportunity to set a new tone for the community, something that works best for them.

The presence of distinguished leadership and the ability to become an recognized leader in the sub-community appealed to participants. In our study, moderators are denoted with an octagon next to their user name and teaching staff is identifiable in other online and offline contexts for the course. To initiate the dialogue, members from the leadership team started asking questions and providing self-answers. Following those self-answers, participants began to post questions and other participants responded. Leaders mitigated the power imbalance by demonstrating their vulnerability [26]. Namely, this normalized the act of not knowing something to participants and demonstrated that leaders could be sanctioned amongst themselves: *"Three benefits are similar*

questions, tailored answers, and trusted responses. I think one overarching benefit [is] receiving a response tailored to my project from a trusted source (TA/Instructor/classmate)" (P89).

A Privy Community with Options. The intimate community size and the prior offline relationships that were built were described by some as an advantage, while others would prefer a bit more flexibility on how their identity is presented. During the mid-study interviews, one participant acknowledged how they would prefer the option to be anonymous in such a familiar community: *I also feel like there should be an option to ask questions anonymously. Sometimes I can get discouraged from asking if I think the question should be obvious* (P123). The comparison of multiple interactions from this study leads to implications that build on the theory of universal designs for learning [103]. In considering support for multiple modes of learning, joining this sub-community with a supplemental transactional forum. Specifically, a synchronous Q&A messaging in a non-archived feedback in the public community [39]. Merging both a community the offers the ability to discuss in-depth projects via proprietary sub-communities while supporting one-one dialogue provide all members are deeper way to engage. The opportunity to ask questions knowing that they are ephemeral and not archived and on the other hand if they are archived, it's only by a community that you already feel comfortable with is a win-win. It would be interesting to comparatively analyze the levels of post privacy and the longevity of visibility in the community.

8.7 Threats to Validity

Internal Validity. An internal validity threat this study faced is the participant pool: selected from a large university upper-undergraduate course. The content of their questions, answers, and comments are based on specific course projects and the infrastructure needed to support the project. An extended longitudinal study with highlighted incentives, similar to on the public Stack Overflow platform, for participation may have influence a changed behavior.

External Validity. The findings from this project generalize well to the broader community of software developers as I conducted this experiment on the live Stack Overflow platform. Stack Overflow hosts teams for organizations who request an instance. To further validate these findings I would like to connect with administrators of other Stack Overflow Team instances and analyze how many contributors have gone on to post in the public Stack Overflow community.

Construct Validity. A study design threat I face is the assessment mechanism to measure the decrease in barriers may not have been sufficient for a couple reasons. First, all 14 barriers were not presented in the survey that participants responded to. I kept the survey brief to increase the likelihood of complete responses. Second, the survey questions did not ask participants explicitly

if they felt that barriers were reduced. I inducted this by a difference in how they rated the presence of these barriers before and after. However, participants could have misinterpreted the question meant for Stack Overflow Team to be Stack Overflow Public and vice versa.

There are many challenges of determining if a perception change. Aside from measuring a difference in activity, another measure is view count of a post. However, view count is not available from the data dump for this private team instance. In order to determine the view count, researchers would have to collect the view count of all posts before the study and after the study to determine if there was a change. Unfortunately, even then the view count can not be connected to participants as that data is only linked to the post.

8.8 Related Work

8.8.1 Online Community Help Resources

Communities for help resources have multiple ways of providing help. Popular resources people turn to when they are stuck on coding problem or other technical challenges are blogs [86], wikis [50], and Q&A sites [110]. Blogs offer a detailed description and often have a walk-through tailored towards a specific audience. Blogs also offer the opportunity for the site owner to comfortably state an opinion or own an approach. Wikis offer a platform where a Community of Practice [63] can collaboratively merge their disparate thoughts on a topic in one location. In this medium, people are informally bound thus, allowing for a range of expertise and support for novices [70]. Q&A communities allow for anyone from a variety of ranks can ask or answer a question. Though it can be a daunting act follow, the primary advantage of that platform is that experts and novices to technical fields gather there. I would argue that the Stack Exchange network, more specifically Stack Overflow, can classify as all of these things which adds to the motivations of why developers are drawn to the platform [3]. Stack Overflow is Q&A platform via the main form of interacting and gain points is via questions and answers. The community can classify as a wiki via permitting any logged in member the opportunity to submit an edit to a question or answer [56]. Finally, the community can classify as a blog due to it's ability to multiple types of discussion that are encouraged in meta-communities to supplement the corresponding core Stack Exchange community. Stack Overflow in particular further allows this through the ability for users to have a developer story that serves as their online curriculum vitae [80]. In essence, Stack Overflow follows a condensed universal design for learning [103].

8.8.2 Formal and Informal Sub-Community Culture Online

An implicit pillar of this work is how social norms of a sub-community enforced can shift perspectives of participation. Using a Focus Theory of Normative Conduct, Morgan et al.

identified that local injunctive norms, recommendations of member behavior, can influence behavioral expectations [71]. Likewise, our sub-community emphasizes injunctive norms targeted at the local sub-community members. Specifically, via responses to the inability to have a downvote reflected to the public community(see Figure 8.2). The perception of access and justification for that access dictates how members feel inclined to engage. I also notice the descriptive norms, describing what people in the community do, to be most explicit in the public sphere through exemplars [59]. In most communities, these people are acknowledged through the gamification of a community through reputation points, badges, and leaderboards [47].

These sub-communities can also serve as transition machinery. In the journey to becoming a community contributors begin to take stock of the different community sub-cultures. On Wikipedia, Bryant et al. found that novices and lurkers find themselves in a staging period where they began to notice the variety of unstructured sub-community that form [15]. For example, sub-communities are also implicitly identified by the tags or keywords associated with a post. For example, across programming languages on Stack Overflow community members have a different format of responding to questions and expectations if it is has a specific tag. These sub-cultures can offer signals to emerging and lurking community members on whether they belong.

8.9 Conclusions

In this chapter, I study the sub-community member advantages, motivations, and interest in engaging a larger public online community. I created and immersed software developers into a Stack Overflow Team for a proprietary programming project. Following this experience, participants identified a shift in perspective in the benefits of a private sub-community which, in like manner, reduced barriers to participation on Stack Overflow. The implication of this work encourage inclusion via the development of formal, private sub-communities in online programming communities. Thus, the evidence in this chapter supports the sub-community claim for my thesis (Chapter 1).

If we further understand what aspects of technical sub-communities an be helpful, can we then integrate them into other online programming communities? How do we do this into pre-existing online programming communities? How do our strategies of integration change in a newly formed online programming community?

In the next chapter, I move towards understanding how signals of identity and technical abilities may influence participation in another online programming community, GitHub.

CHAPTER

9

CONTRIBUTION SIGNALS

9.1 Introduction

Indeed, GitHub profile pages have been designed to reflect the "story of your work through the repositories you're interested in, the contributions you've made, and the conversations you've had" [44]. However, GitHub has evolved to making profile images larger and more visible on a profile page, demonstrating follower and following counts numerically, and the frequency of activity demonstrated visually in a heat map identifiable—all signals that were not quite visible in earlier iterations of the community [21]. More formally, these *signals* are information cues that can indicate attributes such as technical quality [113], which may in turn change perceptions or bias judgments about a project or contributor.

In this chapter, I examine if and how supplementary technical details such as previous contributions, and socially identifying connections such as the avatar image, are used when making decisions about code contributions.[1] To investigate these supplementary technical and socially identifying signals, I designed an eye-tracking study with 42 programmers as they reviewed pull requests. I collected fixation and Areas of Interest (AOIs) data as programmers reviewed the profile page and pull request of mock users submitting a pull request to their team project. Then, I ask them to list which signals on a GitHub profile page are most important to

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[1]Significant portions of this chapter were previously published as D. Ford, M. Behroozi, A. Serebrenik and C. Parnin, "Beyond the code itself: How programmers really look at pull requests," in *IEEE/ACM International Conference on Software Engineering: Software Engineering in Society (ICSE-SEIS)*, 2019, pp. 51–60.

them for managing their own personal identity. From this recollection, I compare the AOIs they actually use in the decision making process versus the ones they reported considering. Finally, I examine the set of strategies used by participants to manage their own personal identities. For example, their approach for deciding which profile image to use on GitHub in comparison to Facebook.

By analyzing the experimental data, I find that:

- While most participants spent their time looking at the code associated with the pull request, all participants examined supplemental information related to previous technical experience and socially identifying characteristics. Some participants even spent the majority of time consulting these supplemental signals.

- Even when they do not think they are, programmers consider social signals of individuals when asked to review code contributions. Thus supporting that social signals can implicitly influence decision making for code contributions.

- When sharing images and other content online, programmers use distinct strategies for socio-technical platforms depending on who's reviewing their content.

9.2   Motivating Example

Abby is an enthusiastic open source developer, who also works as a professional developer. Recently, she had created a pull request to improve a project that she uses heavily in her work. Unfortunately, the pull request was rejected without any comment. This experience left her wondering, was it her code, or something else? One mentor recommended that there might have been something in her GitHub profile that had lead the project maintainer to not trust her potential contribution which caused it to be rejected without looking at it in detail.

Before her next pull request, she discusses with her mentor several possible problems with her profile page and pull request. Looking over her GitHub profile, she and her mentor examined the contents of her profile page and reflected on what might have be perceived poorly by the contributor. First, her mentor pointed out her display name (DN) and commented that she was not using her real name, nor a real avatar image (AI). Her mentor suggested she might instead update these to reflect her real professional identity. Abby was worried about using her real image and name, but decided to try it out. Next, she noticed that her repositories that she had pinned (RE) were older repositories for python code, and maybe she should update them to pin other popular repositories that she has worked on to highlight her experience in games. Finally, she notices that her contribution heat map (HM) is fairly empty when viewed on her mentor's computer. She realizes she can turn on an option to publish contribution activity to private

(a) Profile Page
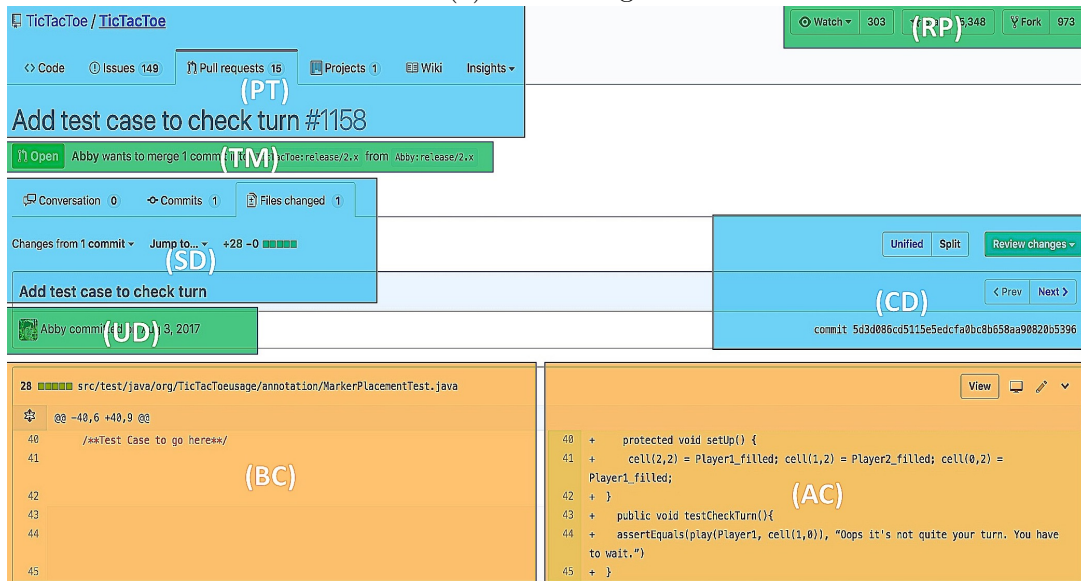
(b) Single Commit of Pull Request

Figure 9.1 `Code`, `Technical`, and `Social` AOIs analyzed on the a) profile page and b) single commit of a pull request

repositories, so that her heat map better reflects her current levels of contributions. The updated profile page is visible in Fig. 9.1a. Abby and her mentor also discuss several ways to improve her pull request. First, she makes sure that the pull request title (PT) properly describes the contribution. She also makes sure that her code (BC and AC), follows best practices for testing by including a test case (See Fig. 9.1b).

Abby submits her next pull request, and it is accepted! Her mentor argues that some of the changes related to *social* aspects of her profile were important. Abby thought that changes related to *technical* aspects, like her contribution heat map and pinned repository mattered. But again she wonders, did the changes she made to her profile and process even *get looked at*? If so, what changes were most important? Was there any evidence to support making any of these changes? Or, did she simply get lucky this time?

9.3 Methodology

9.3.1 Research Questions and Hypotheses

I investigate the following research questions:

RQ1: How do programmers review pull request?

More specifically, how do programmers spend their time reviewing a pull request and where do they look? What elements do programmers consider and does this vary with gender or experience?

RQ2: Where do programmers think they look vs. where they really look?

According to Easterbrook and colleagues, multiple sources of information can helpful to understand programmer behavior. Programmers often do something different in practice from what they say they do when asked [25].

RQ3: What strategies do people use to manage signals for their personal identity?

Online communities generate a culture related to but very different from offline norms. The norms in online communities evolve as they become reinforced by the actions of other community members [35]. I want to better understand strategies people use to bolster or hide certain activities about online code contributions.

9.3.2 Study Design

I conducted an eye-tracking experiment and supplementary pre and post experiment survey to understand participant's interpretation of online code contributions. The goal of this experiment

is to understand what signals programmers employ. To support my analysis, I also segment the elements of the profile page (See Fig. 9.1a) and pull request page (See Fig. 9.1b) into the following groups: 1) *code signals*, elements where the primary content is code, 2) *technical signals*, elements where content provides evidence of technical skills or experience, and 3) *social signals*, elements that communicate unique identifying information about the user.

Pull Requests Mock Ups. To immerse participants in the complete scenario of reviewing an online code contribution I created an environment where they can visually review all elements available from a code contribution. From this pilot study, I determined that pull request mock ups on GitHub is a platform that participants would be most familiar with.

For the eye-tracking experiment, I presented each participant with two pages: a profile page and a pull request page.

9.3.2.0.1 Code Context

Pull requests on GitHub must be submitted to a project. I created a mock-project with a context that participants may be familiar with in order to reduce complexity and stress that can be induced when asked to review something completely unfamiliar. I chose a Tic-Tac-Toe game for the GitHub project for three reasons: 1) it is a game that is cross-cultural and widely known, 2) in the simplest state there are not more than 5 rules for participants to remember, and 3) in the event that the participants are not familiar with the rules, many rounds can be completed in 3 minutes to allow for questions.

9.3.2.0.2 Profile Page

To generate a profile page, I adapted personas from GenderMag. GenderMag [16] is a socio-technical method for modeling and evaluating software's capability for supporting a set of individual problem-solving strategies that tend to cluster by gender. One important aspect of GenderMag is the use of personas during the evaluation process. I adapted the personas to create three profile pages as shown in Fig. 9.2: Abby (identifiable woman), Tim (identifiable man), and Pat (unidentifiable). For Abby and Tim, I updated the GitHub profile with the persona's first name, and image. In GenderMag, Pat is typically represented by both a woman and man persona; in my case, I adapted Pat to a gender-neutral representation by using an identicon for the avatar image.

The profile page also includes descriptive information about the experiences of the submitter such as a map of their contributions over time, a list of popular repositories with programming languages, and a list of commit activity. From Dabbish et al., I know that programmers consider previous experiences and social inferences as a metric for determining when reviewing code

contributions [21]. Thus, I decided to make this content available via the profile page and also relevant to the pull request participants review. I listed two popular repositories reflect other games (e.g., chess and hangman) and including making the programming language of those repositories different (e.g., Python and C#) from the code in the pull request (Java).

All profile pages across personas have exactly the same in experience level. The only thing that varied across the three are the profile image and corresponding name.

(a) Abby   (b) Tim   (c) Pat

Figure 9.2 Profile images of the pull request submitter.

9.3.2.0.3 Pull Request Page

I presented participants with the single commit of the pull request. This page includes a pull request title, whether the pull request is still open, number of lines added, the name and avatar image of the submitter, commit id, the code snippet before it was changed, and the update code block. Fig. 9.3 shows two pull request code snippets—each considers a different rule of the game. The reasonable code snippet, which has no bugs in the code, added a test case to for each player to take turns. The unreasonable to accept code snippet, having 1 bug, added a test case for marker placement in a cell of the Tic-Tac-Toe grid. In total there are 6 pull request pages; both a reasonable and unreasonable pull request code snippet from Abby, Tim, and Pat. To distinguish the two types of pull requests I changed the pull request title, number, commit message, and code snippet.

Participants. I recruited 42 participants through an advanced special topics course in computer science. A prerequisite for this course is for students to be familiar with GitHub. By the end of the course students are familiar with submitting and reviewing pull requests on GitHub. I asked participants demographic information, such as gender, age, country of origin, and whether they identify as a minoirty in their country of origin (Table 9.1). Of my 42 participants, 12 identified as women and 30 as men. 41 participants reported their age ($\bar{x}$ = 25, $\tilde{x}$ = 25 and sd = 1.98).

```
40  +     protected void setUp() {
41  +       cell(2,2) = Player1_filled; cell(1,2) = Player2_filled; cell(0,2) = Player1_filled;
42  +   }
43  +     public void testCheckTurn(){
44  +     assertEquals(play(Player1, cell(1,0)), "Oops it's not quite your turn. You have to wait.")
45  +   }
```

(a) Reasonable code snippet

```
40  +     protected void setUp() {
41  +       cell(0,0) = Player2_filled; cell(1,1) = Player1_filled; cell(1,0) = Player2_filled;
42  +   }
43  +     public void test1(){
44  +     assertEquals(play(Player1, cell(0,0)), "Great job! It is now the next player's turn")
45  +   }
```

(b) Unreasonable code snippet

Figure 9.3 The code snippet (AC) submitted in each pull request.

Device. To study the gaze of participants, I used the SMI wireless eye-tracking glasses. I calibrate the device to record participants at $60Hz$.

9.3.3 Protocol

This experiment included four parts: 1) a pre-experiment survey to understand each participant's experience with online code contributions, 2) a training session to familiarize participants with the task rules and constraints, 3) reviewing two pull request while wearing eye-tracking glasses, and 4) a post experiment survey to collect their recall of the experiment and the purpose of reviewing particular signals. I briefed each participant before and after the experiment about how their findings will be used.

I conducted the experiment in a quiet private room and checked with participants if they can see the monitor in front of them without a need to wear correction glasses. All participants read and signed a consent form before participating.[2]

Pre-Experiment Survey. In the pre-experiment survey, I asked each participant about their experience performing integration tasks, reviewing or submitting pull requests, their general programming experience across languages, and their familiarity with the game Tic-Tac-Toe, which served as the context of the task. I asked participants to score their programming experience on a scale from 1 to 10, 1 as the least amount of experience and 10 as the most experience.

Tic-Tac-Toe Training. Next, I conducted a training session where one author played Tic-

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[2]North Carolina State University IRB 12191,"Evaluating the Existence and Effects of Similar Identity and Identity as Currency in Programming Communities and Projects"

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Table 9.1 Overall Participant Demographics

Gender	Quantity	Age Range	Country of Origin	Minority	!Minority
Men	30	22-33	24 India, 1 Nepal, 1 USA	2	23
Women	12	23-29	5 India, 3 USA, 2 China, 1 Iran	1	10

Tac-Toe with the participant to confirm the rules of the game. After the training session, the researcher reminded the participant of how to win the game and two concepts of the game: 1) each player takes turns and 2) only one marker can go in a position in the grid at a time.

Pull Request Review. Next, the participants put on the eye-tracking glasses and calibrated the glasses using the same computer screen. Before reviewing pull request I reminded the participant of what a pull request is and explained that they would be reviewing the pull request from a teammate based on a Tic-Tac-Toe project. Each participant reviewed first a profile page of the user and then a page reflecting a single commit from the pull request as shown in Fig. 9.1. I then asked participants to respond with the likelihood that they would accept this pull request on a 5-point Likert scale. There are 6 combinations of profile and pull requests a participant could review: The profile page of 1 of 3 personas and 1 of 2 types of corresponding pull request pages. To ensure coverage for future studies, each combination presented to participants was pre-determined and reviewed by more than one participant. The profile page demonstrated either an identifiable man named Tim, an identifiable women named Abby, or an unidentifiable person named Pat. Each profile page was accompanied with a reasonable pull request without bugs or unreasonable pull request with bugs from the same persona. I then removed the eye-tracking glasses.

Post Experiment Survey. In the post experiment survey, I asked participants about the confidence in reviewing code contributions, elements of the profile and pull request they considered, name and image transparency in technical and non-technical online communities, and the opportunity to share additional comments. Following this survey, I asked participants for voluntary demographic information.

9.3.4 Data Preprocessing

I used the *BeGaze* software to categorize eye-movement events into three groups: blink, fixation and saccade. I set up my eye-tracker to visually show us the sequence of the fixations and the gaze point location of each participant (Fig. 9.4). I matched my signals mapping with the sequence of the fixations from the eye-tracker and prepared a sequence of visited AOIs along with their corresponding number of fixations. In addition, I separately documented the time
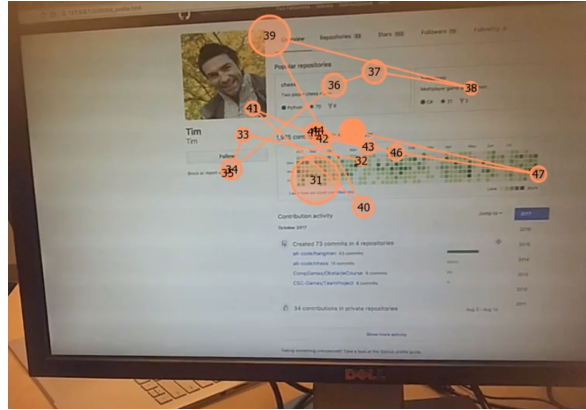
Figure 9.4 I analyzed fixation counts from the *BeGaze* eye-tracking software.

stamps that each participant switched between the profile page and the pull request page. Each fixation lasts for 200-300 milliseconds. Hence, each fixation has approximately 12 consecutive rows in the data extracted from the eye-tracker all of which constitutes for a single fixation in the fixation sequence. To calculate the fixation duration on each AOI, I inspected recordings of each participant and recorded the fixation sequence. I then wrote a script to concatenate the fixation sequence for each visit to my determined AOIs.

9.4 Analysis

9.4.1 RQ1: How do programmers review pull request?

To answer RQ1, I strived to build a theory and understand how programmers across the gender spectrum reviewed pull requests from submitters across the gender spectrum. I had no participants identify as non-binary and thus was not able to sample from that gender. I had 12 participants identify as women and 30 identify as men. Thus, I sampled 10 participants who identified as women and 10 participants who identified as men. To understand how participants spent their time examining the pull request, I measured the number of fixations, number of revisits, and fixation duration for each AOI reviewed.

To understand how programmers of different experience levels review pull request, I sorted my sample based on the reported median fixation duration, number of fixations and the frequency of correct decision. This multidimensional perspective of how programmers spend their time offers a holistic picture of how programmers review pull requests.

9.4.2 RQ2: Where do programmers think they look vs. where they really look?

To answer RQ2, I identified elements of the profile page and pull request page participants considered. In the post experiment survey I asked: "What elements of the displayed profile or pull request did you consider when making your decision?" I qualitatively mapped their description of elements on the profile and pull request page to AOIs I outlined. For example, one participant stated they focus, "*mainly on the correctness of the code. If I am not sure if the code is correct or not, I will probably take the number of contributions/number of accepted pull requests into consideration*". My mock ups did not include the number of pull requests accepted, therefore I mapped this response to AOIs that related to the available content presented: BC, AC, HM and CA (See Table 9.2).

Next, I compared the mapped AOIs from my sampled participants to their AOI visits from the experiment and identified overlap AOIs viewed and reported.

9.4.3 RQ3: What strategies do people use to manage signals for their personal identity?

To answer RQ3, my colleagues and I conducted a thematic analysis on the strategies all 42 participants used to publish content on social media platforms and socio-technical platforms. First, two authors conducted first-cycle descriptive coding on the open responses of strategies used to describe the participant's approach to sharing content online. In the second phase, the same two authors performed axial coding to recognize core strategies and the contextual bounds between each. In the final phase, both authors discussed and converged codes and conducted negotiated agreement [19].

9.5 Results

9.5.1 RQ1: Programmers reviewed code the most, but also reviewed technical and social signals

Table 9.2 demonstrates how participants spent their time reviewing elements of a pull request. In this table, experience is indicated as (H)igh or (L)ow as reported by the participants during the pre-experiment survey. The row labeled 'PR Reviewed' in Table 9.2 describes the reasonable (☻) or unreasonable (☺) to accept pull request the participant reviewed from (P)at, (A)bby, or (T)im. The row labeled 'Decision Evaluation' reports whether the decision made by the participant is a true acceptance (T✓), true rejection (T✗), false acceptance (F✓), false rejection

Table 9.2 Participant Fixations on Areas of Interest

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Participants																				
Experience	H	H	H	L	H	H	H	H	H	H	L	L	H	L	H	L	L	L	H	L
PR Reviewed	P●	P●	P☺	A●	A☺	A☺	A☺	T☺	T☺	T☺	P●	P●	P☺	A●	A●	A☺	A☺	T●	T●	T☺
Decision Evaluation	T✓	–	F✓	–	T✗	F✓	T✗	T✗	–	T✗	T✓	T✓	F✓	F✗	T✓	F✓	T✗	T✓	T✓	T✗
Overview																				
Code Signals	67%	66%	66%	21%	59%	25%	70%	83%	27%	73%	60%	70%	25%	69%	52%	75%	86%	63%	58%	27%
Technical Signals	26%	30%	28%	48%	29%	49%	22%	11%	57%	17%	31%	24%	62%	25%	42%	18%	7%	28%	38%	56%
Social Signals	7%	4%	6%	31%	12%	26%	8%	6%	16%	10%	8%	5%	13%	7%	6%	7%	7%	9%	3%	17%
Code Signals																				
After Code Snippet (AC)	97%	90%	88%	80%	98%	80%	89%	96%	71%	74%	93%	100%	28%	94%	97%	86%	89%	82%	99%	54%
Before Code Snippet (BC)	3%	10%	12%	20%	2%	20%	11%	4%	29%	26%	7%	–	72%	6%	3%	14%	11%	18%	1%	46%
Technical Signals																				
Contribution Activity (CA)	47%	65%	48%	36%	–	18%	11%	–	35%	20%	19%	5%	18%	24%	43%	12%	11%	28%	5%	11%
Commit Details (CD)	7%	1%	–	2%	–	2%	19%	–	–	–	–	1%	9%	3%	–	3%	–	9%	3%	3%
Contribution Heat Map (HM)	14%	16%	17%	12%	–	8%	11%	25%	13%	8%	23%	28%	10%	14%	14%	13%	26%	19%	44%	18%
Pull Request Title (PT)	2%	3%	3%	9%	63%	23%	20%	18%	17%	28%	33%	24%	18%	7%	8%	6%	25%	15%	13%	5%
Popular Repositories (RE)	23%	15%	17%	28%	12%	26%	11%	46%	17%	13%	14%	11%	13%	23%	23%	32%	2%	16%	30%	45%
Submission Details (SD)	6%	–	15%	13%	25%	24%	28%	10%	18%	31%	12%	32%	32%	28%	13%	35%	36%	13%	6%	18%
Social Signals																				
Avatar Image (AI)	25%	20%	51%	28%	13%	16%	7%	64%	26%	52%	35%	33%	7%	24%	50%	21%	74%	42%	35%	46%
Display Name (DN)	16%	24%	4%	8%	–	3%	5%	12%	11%	–	–	–	5%	8%	14%	5%	14%	11%	–	11%
Followers/Following (FF)	6%	19%	19%	6%	–	11%	–	3%	–	–	–	–	–	2%	–	2%	–	–	–	–
Repository Popularity (RE)	–	–	–	–	–	–	–	5%	–	–	–	–	–	–	–	–	–	1%	–	–
Repository Stars (RS)	45%	21%	17%	–	12%	32%	–	3%	14%	–	3%	–	–	8%	–	22%	–	5%	–	13%
To Merge (TM)	6%	4%	–	42%	70%	29%	39%	–	28%	13%	58%	57%	63%	44%	20%	24%	3%	11%	65%	21%
User Details (UD)	2%	13%	9%	16%	5%	9%	49%	14%	20%	35%	5%	10%	25%	13%	16%	26%	10%	29%	–	9%

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Table 9.3 Top 2 Signals Participants Fixated on Longest

Programming Experience	Participant Count	Technical						Social					
		CA	RE	SD	PT	HM	CD	AI	TM	UD	RS	DN	FF
High	12	6	6	6	3	3	0	8	7	4	3	1	1
Low	8	3	3	4	1	4	1	7	6	2	0	1	0

(F✗), or no decision(—). Table sections labeled Overview, Code Signals, and Technical Signals describe the percentage of time a participant spent fixating on each set of AOIs and all sum to 100%.

Overall, I see that participants spent a majority of their time fixating on code ($\bar{x}$ = 57.15%, $\tilde{x}$ = 64.23%). However, they also spent a considerable amount of time focused on technical ($\bar{x}$ = 32.42%, $\tilde{x}$ = 28.45%) and social signals ($\bar{x}$ = 10.43%, $\tilde{x}$ = 7.38%). While most participants focused on code foremost, five participants spent 48% to 62% of their time fixating on technical signals and an above average time on social signals (17% to 31%). To demonstrate my findings on the top signals participants fixated upon, Table 9.3 reflects the top two signals segmented across experience levels for technical signals and social signals. Each cluster is named by their experience level and the fixation combination. I omitted coding signals from this table since all but one participant reviewed both coding signal AOIs.

To interpret how participants reviewed pull requests, I first split participants based on whether they reported an experience level above or below the median ($\tilde{x}$ = 7). I classified 12 participants as high-experience and 8 as low-experience programmers. Next, I classified participants based on their median fixation duration ($\tilde{x}$ = 100575.75 ms), and finally median number of fixations ($\tilde{x}$ = 362.5). I find that based on the self-reported median most men were included in my high-experience sample (n = 9) and most women appeared in my low-experience sample (n = 7). This aligns with previous work that men may over inflate their experience while women do not [12]. Thus, I cannot make supported claims on fixations across genders, but describe similarities across experience levels. My sorting resulted in four groups named for their experience level and fixation pattern:

1) High-Experienced Thinkers: This cluster includes four high-experience participants (M1, M7, M5, M8) who have high fixation duration and high number of fixations. All participants in this cluster made correct decisions (either true accept or true reject) when reviewing their pull request.

2) High-Experienced Glancers: This cluster includes eight high-experience participants (M2, M3, M6, M9, M10, W3, W5, W9) who have a low fixation duration and low number of fixations.

!th
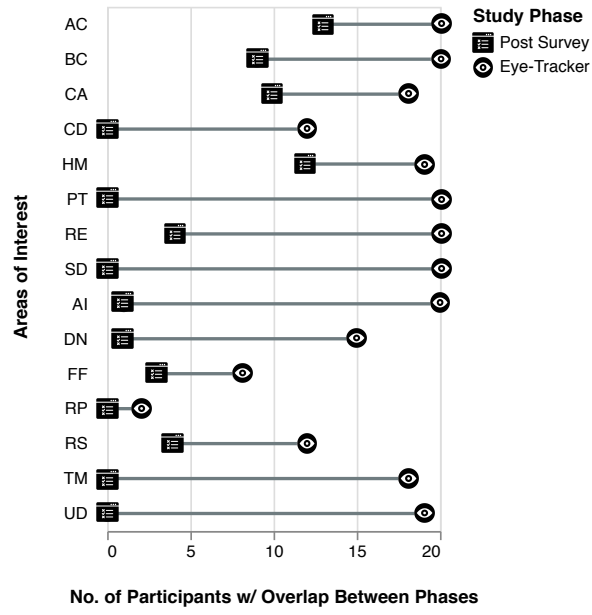
Figure 9.5 For each AOI, the number of participants that reviewed (Eye-Tracker) it via eye-tracking experiment, what they reported afterwards (Post Survey) in the survey, and the number of participants that reported and reviewed that AOI (x-axis).

Decisions in this cluster include 3 correct ones, 3 incorrect ones, and 2 no decisions.

3) Low-Experienced Thinkers: This cluster includes five low-experience participants (M4, W2, W4, W6, W8) who have a high fixation duration and high number of fixations. This cluster includes 1 no decision, 2 correct decisions and 2 incorrect ones.

4) Low-Experienced Foragers: This cluster includes three participants (W1, W7, W10) who are low-experience programmers. Although their fixation count and duration did not conform to a single pattern, all 3 participants in this cluster made corrects decisions on their pull request.

9.5.2 RQ2: Programmers reviewed more social signals than they reported

Overall, I find that 31 out of 42 participants (73%) mentioned that they used the code snippet to make a decision. Specifically, participants mentioned the correctness of the pull request, code complexity, and beautification such as style and formatting of the committed code snippet. 19 out of the 42 (45%) reported that they considered supporting information related to the user's previous contributions. According to my participants, this information includes the number of commits, number of repositories previously submitted to, programming language similarity of prior projects to the one under review, and maturity of their profile demonstrated through their

spread or frequency of contributions across GitHub. Only one participant explicitly mentioned inspecting the submitter's profile image when deciding whether to accept the pull request.

Next, I consider the elements my participants reported considering compared to what they fixated on during the experiment. As expected, I identified that participants fixated on more elements than they described in the survey. Similar to the survey, most participants focused on code and technical signals. In contrast with the survey responses, participants reviewed social signals more than they reported. I demonstrate this in the ranged dot plot across my sample of participants in Fig. 9.5. In this figure, each row demonstrates the number of participants who recalled using an AOI in making their decision, and the number of participants who examined the AOI. A longer distance between the two points illustrates a larger discrepancy in self-reported use versus observed fixations. For example, only one participant explicitly stated they used the avatar image (AI) in their decision, yet all participants fixed on the AI.

9.5.3   RQ3: Programmers use different strategies on GitHub than on Facebook to protect their identity

My colleagues and I identified five thematic strategies programmers used to publish content online in technical and social communities that revolve around the ability to be trusted and remaining safe when sharing aspects of their identity. I supplement each theme with a quote from my participants.

Stay aware of image presented and how they will be perceived on each platform. Online communities encourage uploading an image to be associated with your profile. Importance of avatar images is further stressed by the fact that during the eye-tracking experiment *all* participants have looked at the profile image of Abby, Tim or Pat. In my survey, participants mentioned how sharing that image can make people confident that "you are who you say you are" and how the image used to convey this varies across platforms: *"People feel more confident if they can see image and name of someone either in technical communities and social media. I publish academic image in technical media and casual images in social media." (S14)* Participants expressed that it was important to be easily recognized: *"Name should be Full Name and image should be decent and help others in easily recognizing me." (S19)*

The ability to be recognized became even more important after meeting offline in order to maintain that relationship online: *"It usually happens that you have met someone like in university or conference and you might forget someone's name, but you can recognize them with their faces." (S15)* Participants noted the value of having an online identity that is linked to your offline presence. However, these strategies often varied based on the frequency of use. One participant goes on to say how it helps to establish your "virtual" presence: *"Publishing your name and image in technical as well as social media platforms is a good way to personalize the*

"virtual" aspect of your life. Yes, it varies across communities. I tend to use the above strategy for the platforms that I use more often." (S27)

Make the code stand alone, regardless of the name attached. Aside from what a person looks like, their name is what is used to recognize them. Users are required to enter a display name when they join a community. Likewise, it is one of the first identifiers shown when interacting with another others. In fact, 3/4 of the experiment participants fixated on the display name of the submitter. Participants referred to it as their main identity: *"I publish my name everywhere because that is my main identity." (S11)*

Participants described how they segment their names on different platforms. For example, one participant indicates that they do not use their name on certain platforms because the work should be able to stand alone regardless of their name: *"I prefer using my real name on social media platforms but I use other names when it comes to technical communities, I've different accounts for the different kinds of work. [...] It maybe because my code has nothing to do with my name or my image, the code needs to talk for itself." (S26)*

When in doubt, use an anonymous name. When engaging in online communities, it can be hard to know who is on the other end of the computer. It is also not clear what their intentions may be. Thus several, participants saw it to be very important to remain safe through anonymity: *"For privacy concerns, using a nickname or being anonymous can be a safe way to interact." (S37)*

Participants placed conditions on the level of anonymity. One participant described how they to use a pseudonym based on the community's reputation. Another participant described that unless the community is based on merits, they would remain anonymous. *"When I am using technical communities, and I sense it is a very reputable place and places merit on the content of the question and trollers won't be supported, I include my own information, otherwise I prefer to go anonymous." (S24)*

From the reservation of being stereotyped, one participant mentioned they base their profile on the content they are sharing at a given moment: *"I look for the purpose of what I'm publishing, for if it tends to attract people into stereotyping me, then I omit posting my name/image, else I go for it." (S33)*

Several participants also expressed that bias may exist in how users review content in technical communities. One approach participants have taken to protect themselves is to maintain a gender-neutral profile: *"I used gender neutral alias for websites like technical communities, because I find that I get better help when asking questions or answering them." (S42)*

Complete the online profile to be perceived as trustworthy. Humans use visual cues to build trust—an important factor in how people decide to engage with each other [11, 24]. In virtual spaces, users no longer have that signal to determine trust so they use others. Participants

described strategies they use to be perceived as trustworthy. For example, one strategy for this is to maintain the same online identity that is used in the offline world and how *"such familiarity gives a feeling of trust."(S15)*

Other participants noted that keeping a complete online presence can make you seem like a 'complete person' worth engaging with: *"I usually try to keep my profile complete across all platforms"(S18)* Although participants claimed they tend to be trusted by being perceived as a real person, they also take measures to 'roll with the tide' and follow what others do. In particular, one participant expressed how they tend to conform to the norms of what existing community users do so that they can also be perceived as trustworthy: *"In communities where most people share (etc. Facebook), I share [a lot]. In communities like GitHub, people usually use anonymized id and pictures, and I intend to follow the same rules, so I don't look 'different' and 'unprofessional'."(S40)*

Create personal rules for sharing content based on the platform's primary function. Communities like Facebook and GitHub have primary functions that vary how user find value in each platform. I can determine primary functions of a community based on what the user can see once they log in. For example, on Facebook users can log in and write a new status update and catch up on activities a network of friends have shared. Likewise, on GitHub, users can follow the activity of peers in the context of repositories; which can contain more than just code.

Participants described how they hone in on the primary function of a community and use their internal compass to decide what is acceptable to share in one community over another—the technical audience versus the less technical audience: *"Technical communities are more focused on solving problems, writing code whereas platforms like Facebook are more focused on sharing media. The image used by me on technical profiles are more formal and the content is to the point whereas in other social media profiles, the images and content are more informal." (S30)*

Participants also go on to mention how they take advantage of their perceived primary functions of each community. Several participants highlighted how they use some communities to log work: *"In communities like GitHub, Slack, I build a profile such that I can track all of my content for future use." (S33)*

Several other participants went on to acknowledge how they use the more social communities for non technical work such as music: *"It depends upon the type of community and its basic purpose. Like GitHub is for code and Facebook is for general personal information like where you live, what type of music you enjoy etc." (S25)*

9.6   Discussion

My study shows that when reviewing pull requests, developers examine a much broader spectrum of signals than they report, and subsequently more identity-based signals than they recall. This finding is unexpected since the general size of social-related AOIs are small and scattered throughout the pages—the total area occupied by all social signals would fit in a single technical signal (CA). Despite this, participants still managed to consistently view social signals: All participants inspected at least one social signal (e.g, AI, DN, TM, or UD) that could allow for possible identification of demographic factors associated with the submitter, such as nationality, age, or gender. However, does simply viewing content necessarily mean that the information seen will influence the decision about a pull request? I cannot be sure; however, Just and Carpenter's eye-mind hypothesis argues that fixations and cognition are inexorably linked [57], meaning that fixations and revisits are strong indicators of cognitive processes. Further, some have argued that developers do not even look at social signals at all [73]; yet I now know that is not true. In short, my study finds that developers do pay attention to these signals and supports the notion that these factors can indeed implicitly influence decisions on code contributions.

From a broader prospective, these signals can be seen as representing the submitters' social and human capital: human capital refers to individual's ability while social capital is derived from interactions with others [17]. Such a capital can be made explicit using reputation scores as, e.g., customary at Stack Overflow, or visualized using badges akin to those used on GitHub to represent the status of a project [113]. Qiu et al. have shown that the more often people participate in projects with high potential for building social capital, the higher their chance of prolonged engagement [89]. Alternatively, one can design a "coders anonymous" GitHub-like platform by removing all social signals, hence forcing the integrators to focus solely on the code change proposed and the technical signals. Such a system would be much closer than GitHub to the ideals of open source as a meritocracy [34] and would protect privacy of the contributors similarly to existing solutions such as Anonymous GitHub, Gitmask or Anonydog.[3] GitHub itself moves in the opposite direction by increasing size of the avatar images and emphasizing a developer's 'personal brand' by spotlighting features such as the contribution heat map. In the future, platform designers must be more mindful in balancing the power of signals that can amplify bias or harm against users, while still providing the mechanisms for users to freely evaluate the merits of potential code contributions.

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[3]https://livablesoftware.com/how-to-anonymize-github-activity/

9.7   Limitations

Like many empirical studies, this experiment has its limitations. I have chosen Tic-Tac-Toe as an example and provided a Tic-Tac-Toe training as part of the experiment to ensure that all participants are familiar with the rules of the game, and hence, can distinguish between a reasonable and an unreasonable pull request. To reduce the complexity of the task, I recruited participants familiar with the concept of a pull request. Still, and despite my best efforts, four participants accepted an unreasonable pull request, one participant rejected a reasonable pull request and three participants could not make a decision. It is still possible some participants have been more familiar that others with GitHub pull requests or with Tic-Tac-Toe and this might have affected their gaze behavior or correctness of the decision making. Although participants indicated that they were familiar with pull requests, they may have taken time to get acquainted with the layout of the first commit. This could have led to a more dispersed gaze pattern.

For my profile mock ups, I used Caucasian-presenting profile images of young people and Western names (Abby, Tim, Pat) in order to not conflate the gender of the submitter with additional identity attributes such as age, race or ethnicity. However, while age-wise Abby and Tim seem close to participants,[4] the lion's share of the participants list their country of origin to be India; a country where Caucasian people are not the majority. As facial resemblance is also known to enhance trust [24], the lack thereof might have affected the likelihood of participants identifying with the submitter, and subsequently the time spent by the participant looking on the avatar image and display name. Likewise, I did not explicitly state genders of Abby, Tim, or Pat. I tried to recruit participants of different presenting genders and report gender of the participants as described by the participants themselves (which only include men and women).

I also understand that RQ3's distinction between online technical and social communities is a hard line to draw. Thus, I based this distinction on how participants use these spaces. For example, Facebook can be used as both a social space to share videos of funny cats but also a place to connect with others professionally through groups.

9.8   Related Work

Understanding the mechanisms behind acceptance or rejection of pull requests goes beyond the value of the code snippet. Prior work explores how transparency [21], impression formation [68], and socio-technical associations [115] influence pull requests acceptance. Further, the action(or inaction) can also demotivate the contributor from submitting future pull requests [102]. However, as opposed to using primarily interview methodologies, as previous studies have, I designed an eye-tracking experiment to evaluate these factors. My experiment confirmed observations of

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[4]GenderMag states that Abby and Tim are 28; age of the experiment participants ranges from 22 to 33.

these studies that both technical and social signals of the pull request influence the developers' decision on whether the pull request is to be merged. Moreover, my study has provided further insights in relative importance of different signals: the newly submitted code snippet(AC) was much more often looked at than the previous code snippet (BC), and while all participants have looked at the avatar image(AI), most participants fixated on other social signals for longer periods of time.

Pull requests have been used as a lens to study gender differences and bias in open source [107] as well as the impact of gender-diversity on productivity [120]. While I have recruited participants of different genders for my experiment I do not compare women and men or acceptance of Abby's, Tim's and Pat's pull requests. Such a comparison would be interesting and fruitful but it would require a larger number of participants to report meaningful results.

The relevance of social signals in pull requests implies that is important to manage ones own identity in online technical communities. My study concurs with Goffman's theory of self-presentation [45]. Goffman compares individuals to actors that have to navigate both 'front stage' (e.g., communication in the office) and 'back stage' (e.g., candid talk with friends after the working hours). Building on Goffman's insights, changes in self-presentation based on the audience have been observed both in face-to-face [64] and more recently in online communication [69]. Similarly, I find that programmers also explicitly take the audience into account when determining their online presence: e.g., by deciding what kind of images and names to use, and whether to disclose their gender.

Eye-tracking experiments are a validated approach to understand the nonverbal cues used and challenges encountered by programmers. Fixation and scanpath data coupled with a supplementary metric to evaluate the outcome has helped better characterize how programmers use tools and infrastructure [126]. For example, Barik and colleagues able to combine a combination of fixations, revisits, and task performance to interpret error reading styles in an IDE [8]. Likewise, Behroozi and colleagues used a similar approach to understand confusion during technical interviews at the white board [10]. This work follows a similar methodology to study how programmers' review pull requests beyond what they have the ability to vocalize.

9.9 Conclusion

In this chapter, I conducted an eye-tracking experiment with to obtain a more granular understanding of which of pull request elements are considered. Similarly to previous studies, I observe that both social and technical aspects are being taken into consideration when deciding upon pull request acceptance. Moreover, I observe that *many more* social aspects are being considered during the experiment than reported during the post-experiment survey. In particular, I observed that all participants inspected at least one social signals that could allow for clarification of

the submitter's identity. Given the importance of social signals, I also studied the strategies developers use to decide which signals they produce on technical platforms, such as GitHub. Concurrent with the importance of the avatar images and display names in pull request acceptance decisions, respondents highlight importance of those signals they produce on GitHub as a means of social capital. Furthermore, these strategies address such issues as safety, trustworthiness, and differences between representation on technical (GitHub) and social (Facebook) platforms. Thus the evidence from this chapter supports the identity-based signal claim of my thesis: By incorporating identity-based signals, I can help programmers overcome these barriers and significantly increase participation in online programming communities (Chapter1).

In the next chapter, I revisit the key contributions of this dissertation and its associated works. I also discuss future directions of this body of work.

CHAPTER

---- 10 ----

CONCLUSIONS

10.1 Thesis Revisited

The thesis for this dissertation is:

> 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, introducing mentorship, and understanding sub-communities, we can help programmers overcome these barriers and significantly increase participation in online programming communities.

In this dissertation I describe studies I have conducted to gain an in-depth understanding of how participation in online programming communities can be influenced. First, I design a conceptual framework of inhibitors to participation by conducting an empirical investigation of barriers in online programming communities (Chapter 4). Using this conceptual framework of barriers, I design several studies to understand what community mechanisms can influence participation. From this work I have been able to define the concept of *peer parity* and how the access to congruent identity signals can influence participation among women, understand how e-mentorship can increase participation of novices, dive deeper into how the discretion of sub-communities can influence participation, and how signals of identity are taken into consideration when participating in other online programming communities.

10.2   Future Work

In this section, I describe a few future directions branching from the my findings. These directions include understanding how offline communities can influence participation, the proximity of these communities to our identity, and suggestions for community infrastructure.

10.2.1   Transitions from Offline to Online

This dissertation used a framework of barriers describing inhibitors to participation that were caused by online interactions. However, many of the solutions or work-a-rounds participants reported were provided in their offline communities. This begs us to ask the question: How does offline interaction influence online bonds within online programming communities? How does who participates in our offline sub-communities that influence our online sub-communities? Do developers without access to private, offline technical sub-communities also find it challenging to succeed in online programming communities? It would be interesting to discern how offline relationships with the developer community can support the survival strategies of those entering technical communities online.

10.2.2   Guidance from those in Close Proximity

The aforementioned studies highlight findings on how identity and guidance independently influence participation. Extensions of this work can draw attention to what may lie at the intersection of these community attributes. For example, a few participants from the Contributions Signals (Chapter 9) study reported that if the code they were reviewing was from a developer resembling, via avatar image or name, someone from their country of origin they would be even more critical. It would be interesting to study how this in-group homphily may influence the code review process. Specifically, how does the proximity of the code contributor to the developer's identity influence the decision to accept or reject their technical contributions to online programming communities? At the junction of peer parity and stratums of leadership in online programming communities, how do mentors with a close proximity to the mentee's identity influence engagement? How may that increase the likelihood of participation for developers from marginalized communities?

10.2.3   Community Infrastructure

From conducting these, I pose that ultimate indicators of success of engagement are when leaders are identifiable and the community provided explicit indicators of how to participate. Online communities should:

1. Have a community owner or builder be transparent about community challenges and list how they will move towards being inclusive (e.g.,Stack Overflow CEO making a statement [99]).

2. Provide implicit cues for how to encourage engagement via participation. This will draw the attention of novice users to the main form of interaction expected in the community (e.g. the highlighted green "Open a pull request button" on GitHub).

3. Build mechanisms in place to enforce a code of conduct and give users a voice in the process—a community for the users by the users. Building mechanism to encourage this procedural justice [116] makes communities be perceived as more fair and can in turn foster inclusion. (e.g., Contributor Covenant [27]).

But how do we encourage online communities to do this? What mechanisms can be build to help community builders adopt these recommendations?

10.3   Epilogue

What does a successful, inclusive online programming community look like? I would say we are still not sure. I hope this dissertation keeps us on the right track to get there.

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APPENDICES

A

EXTENDED BARRIER INVESTIGATION (CHAPTER 4)

This appendix extends Chapter 4's `Empirical Investigation of Barriers`. Specifically, I dive further into the methodology used to identify barriers and study materials used.

A.1 Methodology

A.1.1 Research Questions

The three research questions of this study are:

RQ1   What **barriers** do women face on Stack Overflow?

RQ2   How do barriers vary by **gender**?

RQ3   How do the rating of barriers vary by **other factors**, such as site usage and experience?

A.1.2 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

Table A.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

experiences. I interviewed female developers to understand how they use Stack Overflow. I recruited female developers from a variety of usage levels (no accounts, occasional contributor, and active contributor) and experience levels (students and professionals). In addition, I 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 person, I can compare factors that kept her returning to the platform to the factors that discouraged users from the first round of interviews.

Interview Script. To create my interview script, I seeded questions based on potential factors listed in Vasilescu et al.'s work [118], and from reasons listed in a Stack Exchange post titled "Why do you post to Stack Overflow?".[1] I 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:

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

- 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 I 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. I received 25 responses from the recruitment questionnaire. I required respondents to select a time slot to interview as part of the recruitment questionnaire. I interviewed the 21 participants who attended their scheduled time slot. Interview participants received no compensation for their participation.

I then contacted a high ranked female user on Stack Overflow. This user was ranked in the top 100 users of all time listing.[2] I 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 A.1. The participant demographics consisted of nine professional software developers working in industry, twelve students, and one who identified as both.

Protocol. 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, I conducted interviews with the same interviewer for 30 to 45 minutes. I 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. I scheduled an online video for the interview through email correspondence. With the high ranked user, I discussed several themes that arose from the other user interviews and focused on how her experiences compared and contrasted with other users.

Analysis. I first transcribed the audio recordings for each interview. My colleagues and I 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

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

describing a participant's experiences while programming, and statements describing barriers deterring them from using Stack Overflow. For the purposes of this dissertation, I 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 [92]. The 14 resulting barriers are described in Section A.2 and summarized in Table A.2.

A.1.3   General Survey

I constructed a survey with the barriers identified from the interview participants. The survey consisted of questions regarding the ratings for barriers and demographics. I 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. I 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. I distributed the survey to the general developer population. I sent targeted emails, posted to programming forums, contacted large corporations, and posted in computer science Facebook groups. Survey participants received no compensation for their participation.

Analysis. I 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). I used the ratings received to derive the collective ranking of barriers per population.

A.2 Outcome: Resulting Barriers

Table A.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 Interactions	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

To answer RQ1, I 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. I am not suggesting that only females would be affected by these barriers, or that the barriers are in some direct way about their gender. However, I am 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 A.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, I would ask if they might answer more questions if they could gain a badge or edit an incorrect answer. Many participants were completely unaware of most of the features I 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 [72]. One effective strategy for raising awareness occurs from serendipitous observation of other peers using a new feature [72]. 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. [88] 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 [96]. 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 [36]. 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 [101] 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

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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 [40]. 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 [53]. 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."*

A.3 Outcome: Ranking and Rating Barriers.

Although I identified barriers through interviews, I want to identify which barriers can have a strong impact across genders and other groups. By distributing a survey, I 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, my colleagues did not identify a new barrier. With the survey data, I answer my remaining research questions related to the ranking, differences in gender, and influences of other factors on barriers.

A.3.1 Gender Comparison

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	

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

To answer RQ2, I performed a statistical analysis to identify contribution barriers across genders and understand how the populations differed in their response. I performed a two-tailed Wilcoxon rank-sum test on the ratings given to each barrier to compare populations. Table A.3 demonstrates that 5 out of 14 barriers had a statistically significant difference between females and males. To be clear, I am 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 I identified cannot conclusively occur from gender differences alone. All barriers with α = .05; α = .0012 after
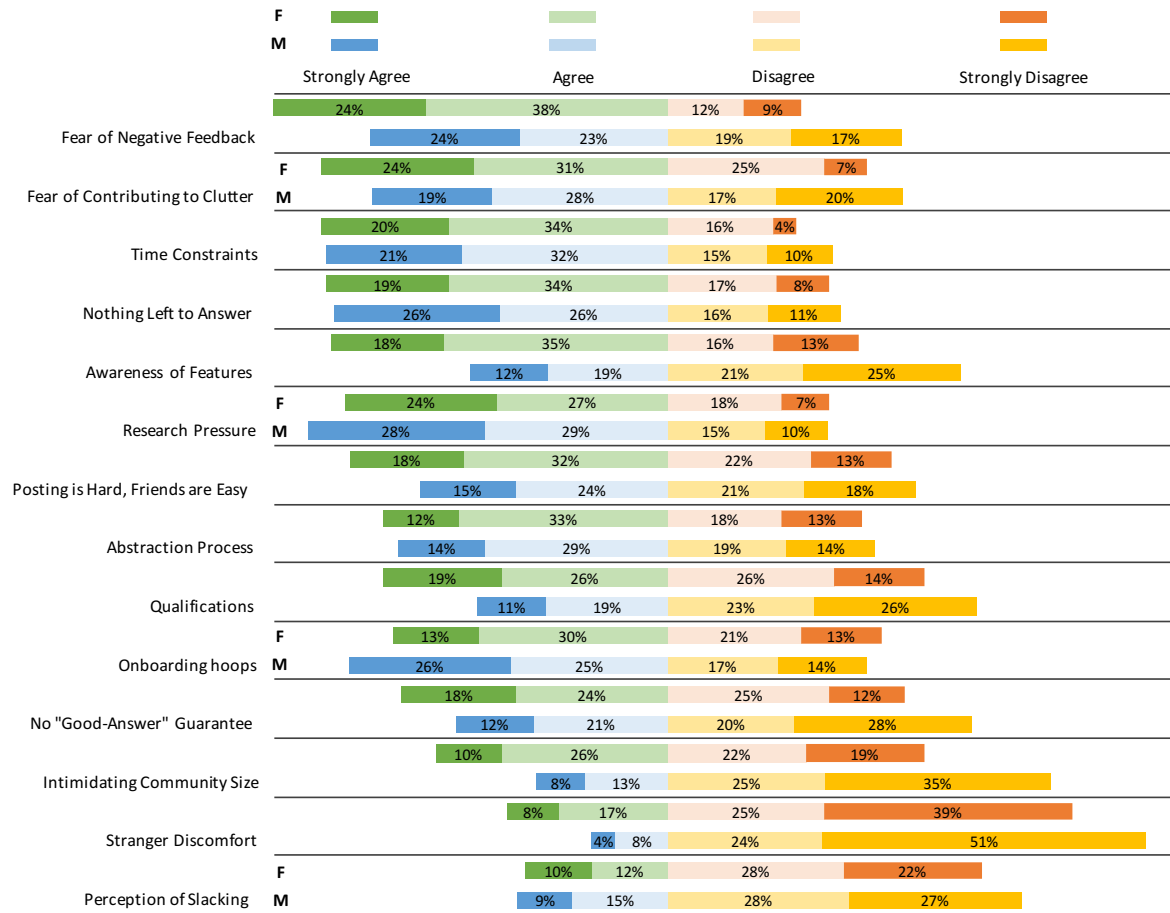
F Strongly Agree   Agree   Disagree   Strongly Disagree
M

Fear of Negative Feedback
F: 24% | 38% | 12% | 9%
M: 24% | 23% | 19% | 17%

Fear of Contributing to Clutter
F: 24% | 31% | 25% | 7%
M: 19% | 28% | 17% | 20%

Time Constraints
F: 20% | 34% | 16% | 4%
M: 21% | 32% | 15% | 10%

Nothing Left to Answer
F: 19% | 34% | 17% | 8%
M: 26% | 26% | 16% | 11%

Awareness of Features
F: 18% | 35% | 16% | 13%
M: 12% | 19% | 21% | 25%

Research Pressure
F: 24% | 27% | 18% | 7%
M: 28% | 29% | 15% | 10%

Posting is Hard, Friends are Easy
F: 18% | 32% | 22% | 13%
M: 15% | 24% | 21% | 18%

Abstraction Process
F: 12% | 33% | 18% | 13%
M: 14% | 29% | 19% | 14%

Qualifications
F: 19% | 26% | 26% | 14%
M: 11% | 19% | 23% | 26%

Onboarding hoops
F: 13% | 30% | 21% | 13%
M: 26% | 25% | 17% | 14%

No "Good-Answer" Guarantee
F: 18% | 24% | 25% | 12%
M: 12% | 21% | 20% | 28%

Intimidating Community Size
F: 10% | 26% | 22% | 19%
M: 8% | 13% | 25% | 35%

Stranger Discomfort
F: 8% | 17% | 25% | 39%
M: 4% | 8% | 24% | 51%

Perception of Slacking
F: 10% | 12% | 28% | 22%
M: 9% | 15% | 28% | 27%

Figure A.1 Diverging stacked bar chard comparing the distribution of barriers across a binary gender

Bonferroni correction [125] have been highlighted in green in table A.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 A.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/women and males/men 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 presented in Figure A.1

A.3.2 Additional Factors

I 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, I reviewed 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)*. I observed statistically significant differences (Wilcoxon rank-sum test with Bonferroni correction α = .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. I also compared survey responses from those who identified as full time developers *(n = 1003)* to those who did not identify as such *(n = 467)*. I observed statistically significant differences (Wilcoxon rank-sum test with Bonferroni correction α = .0012) between full time developer and non-full time developer ratings of two barriers. I found that full time 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*.

A.4 Interview Script

Interview Script

Briefing

Thank you for joining us today _____. We appreciate your voluntary help with this research study. We are interested in hearing about your use of the popular Q&A Site StackOverflow. As a reminder, for the sole purpose of accuracy this interview will be recorded. In addition, throughout the interview I will be taking notes. Your identity will remain anonymous as mentioned in the consent form. You may sign the consent form and return to me if you wish, but I only need your oral consent to participate.

With that being said, do you consent to participate?

Great. I'll begin the interview.

Interview Questions

<u>**Getting to know you[K#]**</u>
1. Tell me a little about yourself: What's your area of interest? What type of programming projects do you work on?
2. When working on programming tasks, where do you seek answers?
3. How do you use StackOverflow?
4. Do you have an account on Stack Overflow?
5. When you used it do you post questions? Answer questions?
6. When is the last time you used StackOverflow?
7. Can you tell me more about that experience?
8. As a female, do you feel like there are aspects of SO that are not geared for you?
9. Do you have a friend who has an account or actively used the site?
10. Do you have a female friend who has had a negative interaction on the site?
11. If you saw a wrong answer on StackOverflow, would you want to correct it?

<u>**Communication[C#]**</u>

1. How do you feel about the communication on StackOverflow? How people speak to each other?
2. Do you enjoy the concept of helping people online?
3. How about helping people that you know?
4. How about helping strangers?

<u>**Gamification[G#]**</u>

1. Are you familiar with the Badges on the site?
2. Are you familiar with the process of posting bounties? It's the process where a user can spend reputation points to get a question answered and then award those points to a person.
3. How have they encourage you to use the site?
4. Did you know can elect moderators on the site?
5. Is there another game that you think should be played on SO? One that you would play.

Incentives[I#]

Are any of the following incentives to use the cite for you:

1. To climb up the user pages and be higher than the highest rank user (John Skeet, Jeff, Joel, etc).
2. To gain reputation to be able to have more ability in the system
3. To gain badges, just for the fun of having them
4. To help others because you like helping others
5. To help yourself; because, you often learn things by having people criticize your answers
6. To make you feel good about yourself by helping others
7. Because you want to promote your own products or services in your 'about' description block.
8. Because you want to be known in the programming world
9. Because you want to expand your world of known topics
10. Because you want to get more in depth knowledge of topics you already know
11. Because you like to be heard, it's a good alternative to having a blog
12. ~~Because it's fun to be higher in user rank than Jeff, Joel, and John Skeet (the highest rank users).~~
13. Because it improves your communication skills.
14. Because you like to be reassured that you are right.
15. Because you like to know when you are wrong.

Scenarios[S#]

1. Imagine you're on the site and you see a question you know the answer to. Would you answer it?
2. Imagine you're on the site and you see an answer that's wrong. Would you edit it?
3. Imagine you are on the site, you see a question and you have 60 seconds to answer it and get a reward. Would you answer it?

Follow up[F#]

1. Now that you know about all these features would you be more inclined to use the full features of StackOverflow? How about to create an account?
2. What that one thing that would make the site better for you?

Debriefing

Thank you again for participating in today's study. If you have any questions please don't hesitate to email me. If you think of any other comments that you forgot to mention during today let me know.

A.5 Barrier Survey

Stack Overflow Usage

We are researchers conducting a survey on how software developers use the popular Q&A site, Stack Overflow. We appreciate your voluntary help with this research study.

Many users on Stack Overflow never contribute to the site -- rarely asking questions, answering questions, making comments, or voting. For those who do contribute, they often compete to gain reputation points, which enables them to unlock more features on the site.

Please rate the following possible barriers in the degree that they stop you from contributing more on Stack Overflow.

* Required

1. **Abstraction Process** *
   When asking a question, 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.
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

2. **Fear of Contributing to Clutter** *
   I feel my question might just be a duplicate or unimportant question, so I refrain from posting.
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

3. **Fear of Negative Feedback** *
   I fear my posts being harshly criticized by users on the site.
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

4. **Stranger Discomfort** *
   I feel uncomfortable interacting with and relying on help from strangers online.
   Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

5. **Intimidating Community Size** *

I feel intimidated by the large community of users. I instead prefer connecting with a smaller and more intimate group.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. **Awareness of Features** *

I feel I am simply unaware of and have not explored the more advanced features of the site.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

7. **Qualifications** *

I feel my expertise or answers would not be of any help to anyone else.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

8. **Nothing Left to Answer** *

I feel all the easy questions have already been answered, leaving only hard questions.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

9. **Perception of Slacking** *

When working on the job, I feel that I should not be spending time answering questions on Stack Overflow for my own personal benefit.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

10. **Onboarding hoops** *

I feel figuring out the unspoken social etiquette and community standards is too much work.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

11. **Research Pressure** *

When posting a question, I feel discouraged by the amount of work I have to do to prove that I'm not asking a duplicated question.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

12. **No " Good Answer" Guarantee** *

When posting a question, I fear not getting a good answer.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

13. **Posting is Hard, Friends are Easy** *

I feel the process of posting question is too cumbersome compared to other resources such as asking friends for help.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

14. **Time Constraints** *

I feel making contributions on Stack Overflow, even just finding an unanswered question, requires more time than I have.
Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Demographics

15. **What is your gender identity?** *
Mark only one oval.

◯ Female

◯ Male

◯ Other: _____

16. **What is your level of experience with Stack Overflow?**

Select all that apply.
Check all that apply.

- [ ] Lurker (I use the site to find answers without contributing)
- [ ] I have a StackOverflow account
- [ ] I post answers to questions
- [ ] I post new questions
- [ ] I vote on responses
- [ ] Other: _____

17. **Is there a barrier for you to use StackOverflow that was not already listed on the previous page? If so, what is it?**

_____

_____

_____

_____

_____

18. **What is your employment status?**

Select all that apply.
Check all that apply.

- [ ] Full Time Student
- [ ] Part Time Student
- [ ] Full Time Developer
- [ ] Part Time Developer
- [ ] Self-Employed
- [ ] Self-Taught Programmer
- [ ] Other: _____

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B

COMMUNITY E-MENTORSHIP STUDY MATERIALS (CHAPTER 7)

This appendix includes the study materials of Chapter 7's `Community Mentorship` project.

B.1 Mentorship FAQ

Mentorship Experiment FAQ

This is for mentors only

Example usage:

Example question

Draft answer here - any mentor can write draft questions/answers - heading 3 style

PLEASE ADD YOUR NAME when adding or making major changes. - Thanks!

TL;DR (Updated 11 August 2017) - by [Anonymized Author]

If you don't read anything else, read this.

- **REMEMBER: IF YOU ARE IN "PRIVATE MENTOR CHAT" THE CHAT IS ON. PLEASE DO NOT KEEP MENTOR CHAT OPEN IF YOU ARE NOT AVAILABLE TO MENTOR.**
- When a mentee enters "Asking a Question" chat, **claim them in "Private Mentor Chat"** by saying something like *"I'll help [username]."* Then, click the link to follow them to the correct room.
- Once you've claimed them, **see if they respond to [Anonymized]**, and once they do, go ahead and let them know you're going to read their question and get to helping.
- It's obvious but bears repeating: **WE WILL NOT ANSWER PROGRAMMING RELATED QUESTIONS IN CHAT.**
- You'll want to **let them know that they can edit their draft**: *"If you make edits to the question right here in chat (using the "edit" button on your draft), we can see an updated version."*
- There are many possible kinds of issues that may need your help. Here are a few scenarios:
  - Their question is **more appropriate for another Stack Exchange Q&A site** - let them know and link them there (but only if you're <u>positive</u> it doesn't fit here and positive it fits in the other site)
  - Their question is **obviously homework** - help them make the question specific to what they're having trouble with (make it a good question). Guidance on homework questions [here](#).
  - Their question is **missing critical information** - ask them for that info while you're helping them
  - The **phrasing is unclear** - ask them what they mean by X or Y and advise them to clarify their wording
  - Their question is a **duplicate** - tell them how to find duplicates, or even grab it yourself if it's easy
  - Their **grammar/spelling isn't great** - advise them to edit, and if they're struggling, you can help them with certain phrases (use your judgement here - **as long as it's comprehensible, let it go**)
  - The issue they're having is the result of a **code typo** - you can (and should) tell them about the typo
- **Teach them to fish** - show them how to craft a great question so they can do it themselves next time! Almost everything you say to your mentee should end with a question mark (?)
- Try to avoid SO lingo or acronyms (like MCVE) - you can introduce them if necessary, but **make sure to explain them**. For example, if you want to talk about MCVE, you can say, *"It's good practice to make your examples minimal, complete, and verifiable (frequently referred to as MCVE on the site)."*
- Remember: We want to get them to a good, solid question - **don't nitpick them to perfection.**

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Who's running this experiment? - [Anonymized]

The team includes:

- [Anonymized]-Researcher
- [Anonymized]-Developer
- [Anonymized]-Product Manager
- [Anonymized]-Designer

[Additional team members have been removed for anonymity.]

[Anonymized Mentor]: What should I do if a user isn't taking help well or is resisting your suggestions to an extent where it is challenging to work with them?

[Anonymized Mentor]: Simply let them know that their question will most likely be received poorly when asked on the main site. We can only help users to the extent that they're willing to be helped. If you think that the user could be helped further, you can direct them to another mentor.

If you find yourself getting frustrated with a mentee - you don't need to continue trying to help. Feel free to pardon yourself and let another mentor try if the mentee isn't being truly uncooperative

[Anonymized Mentor]: What happens once the mentees posted their question on the site? Should we also provide guidance to any follow up issues that may arise (Like - "my question is being downvoted", "no one is answering my question")

[Anonymized Mentor]: Outside of the mentoring chat room, our responsibilities are the same as usual. We may give links to the tour, the help center, or meta in the comments of their question, or we may give advice in the mentoring chat room if the mentee is still seeking help there. Try to be proactive, so that they will already know where to look if they have further questions.

[Anonymized Author]: Additionally, we'll observe if people are hanging out in the chat long after their question has been asked. We want to keep the chat high-signal, so if this becomes an issue, we'll figure out a way to address it.

[Anonymized Mentor]: How do we organize the mentoring?, in case that we have multiple mentors on-line, OP needs to speak to one, we can't have 30 people giving advice or can we?

[Anonymized Author]: I think generally, mentors can be hanging out in private Mentor chat, and a couple can hang out in public. That way, when someone enters, someone can "claim them" and head in to help.

[Anonymized Mentor]: The general procedure will be that from "mentor chat" we claim OP, first to claim goes to "asking chat" to help. Other mentors should avoid giving suggestions directly to OP, if they have suggestions they can ping mentor helping OP in the "Mentor Chat".

[Anonymized Mentor]: Please also note from email which group you are in as a mentor, hence give precedence to people in group that is assigned to be active (note sure if we like this, but added anyway, it seem logic if we get a lot mentors that like to help)

[Anonymized Mentor]: Is it acceptable to invite mentees into a one-on-one channel to resolve their issue, and move the messages back to the main chat when finished?

[Anonymized Author]: No, please don't do that. Let's keep all messages in the main channel, and explore the necessity of splitting them out if it comes to that.

[Anonymized Mentor]: This probably is not even possible (if someone has 1 rep, they can't be invited to chat)

[Anonymized Mentor]: What if we know that the question is a duplicate?

[Anonymized Mentor]:If the question is clearly a duplicate, we should point it out to the asker. If they disagree with it being a duplicate, their question should clearly specify *why* it's different from the proposed duplicate.

[Anonymized Mentor]: If it seems like a duplicate, the mentor should suggest the duplicate to OP, if this solves the issue so be it, no question asked. If not it is good that OP include it in question (shows effort) and explains why it does not solve issue.

What should we do if a question is a typo?

[Anonymized Mentor]: Typo questions are a bit more tricky. Usually they require some domain knowledge, and they're not necessarily *off topic questions* at the time of posting, but rather closed for being not useful in the future, once the problem is resolved. If the question is clearly due to a typo, we should notify the asker.

Should we stop people from asking questions ever?

[Anonymized Author]: We should never be "preventing" people from asking a question - we should only ever advise and assist. If there is a situation in which the question is not appropriate for SO, you can strongly advise against posting - let them know what will happen if they do. Ultimately, though, we're trying to increase the question quality on SO and improve the community, but with a carrot, not a stick. :)

[Anonymized Mentor]: What specific rules are applied in the "asking a question" room?

//title is bad, idea is to add some common room ruelzz that help us to keep it nice and clean

[Anonymized Mentor]: Only use the room to talk to OP, if you need to talk to mentor use the "private-mentor-chat"

[Anonymized Mentor]: Keep the "asking-a-question" room as clean as possible, avoid to star/pin message since this can be confusing for OP (seeing stared message on the right that is not related to his question). ???If we are also RO we can also clear stars that an OP did, I have a userscript for that, but not sure if we are RO???

[Anonymized Mentor]: How do we handle multiple OP's at same time in same room?

[Anonymized Author]: General Workflow

When a new user agrees they wish to receive help in formulating their question, they will be able to click a link on the Ask Question page which directs them to the "Ask A Question" room.

Upon joining that room, anyone present in that room that's a registered mentor will be pinged to notify them their help may be needed. Please note - it's best you only attend the room if you're available to mentor - that way you won't receive pings and the room list can be used as an indicator of how many mentors are presently available.

The user seeking help will join the AaQ room and a message will be automatically posted on their behalf similar to:

Note that the mentee has an "edit" link (1) which enables them to edit their post while receiving advice on what changes could be made. When the mentee clicks on that link they will see something similar to the following (kind of a work in progress):

The mentee edits the markdown exactly as they would on the site and when they save changes, the chat message will be updated for the mentor to review. A notice will be added to the room saying that a draft has been edited and a link to the draft in case it's scrolled off screen. Once the mentoring is complete and everyone's happy for the question to go live, then the OP can click the "copy draft back to Stack Overflow" link (2) which'll fill out a new question with details for the OP to click submit :

At this point - the OP hits "Post Your Question" and job's done! Hurrah team!

[Anonymized Mentor]: What should we do when the OP is not ready?

[Anonymized Mentor]: Tell the user to put @mentorName when the OP is ready.

[Anonymized Mentor]: How about proportional percentage of presenting popup for mentees?

Misc observations:

- SO may be the wrong target site for a question - don't be afraid to recommend another site, but bear in mind that recommending other sites should only be done if you're absolutely confident it's on-topic for the target site and definitely off-topic for SO (and won't end up closed/downvoted on the target - we don't want other sites receiving rubbish!)
- Don't be afraid to request further information as in https://stackoverflow.com/help/mcve to make the question as answerable as possible (don't forget the "presume low familiarity with SO and using jargon/acronyms" in the tips though!)

- "Typically greetings are frowned upon." - might be good to consolidate a concise bit of phrasing off either MSO or MSE about why the traditional "pleasantries" aren't required on SO and while they're appreciated just aren't required kind of thing.

- Feel free to point out that people can "edit" their attempt(s) to clarify things as needs be (this may be an iterative process)

Note: If as a mentor you see an access request to the AaQ room - you should ignore it. All users that have clicked the link to receive help via the system will automatically join the room and be able to talk.

B.2   Interview Script

Post-Interview Script [Mentor + Mentee]

Instructions for Researcher:
These questions will be asked during a final video chat at the end of the study. In the essence of time and attention, likert scale questions will also be asked during this time. These question are both for the mentee and mentor - specific questions are labeled and color-coded: purple is for everyone, blue is for mentors-only, and red is for mentees-only.

Thank you again for taking the time to meet with me today. My name is [name] and I'm [job title, description of job, employer].

Today, we'll be reflecting on your participation in the Stack Overflow Mentorship program.

As previously mentioned in the consent form, we'll be recording this conversation. If at any time you would like me to stop the recording let me know. Your identity will remain anonymous.

As a reminder, there are no right or wrong answers here - I'm not testing you or quizzing you or looking for a particular answer. I'm simply interested in your honest opinions and thoughts about Stack Overflow and the mentorship program.

With that being said, do you consent to participate? [Yes/No]

Great. I'll begin the interview. *[BEGIN RECORDING]*

Okay, I've started the recording.

Mentorship Experience - Mentors Only
"On a scale from 1 to 5, please rate your agreement with these statements about your experience as a user of Stack Overflow. 1 being strongly disagree, 5 being strongly agree."

[random order]
- I feel comfortable mentoring a user through creating a question on Stack Overflow
- I feel comfortable suggesting changes to a question to a mentee
- I feel confident in my mentorship abilities
- I found value in my experience participating in the mentorship program
- I feel that my mentorship made a difference in the quality of questions on Stack Overflow
- I feel like part of the Stack Overflow community
- Communicating with other mentors during the experiment was important to me

Site Participation - Mentees Only

"On a scale from 1 to 5, please rate your agreement with these statements about your experience as a user of Stack Overflow. 1 being strongly disagree, 5 being strongly agree."

[random order]
- I feel comfortable posting a question on Stack Overflow
- I feel comfortable answering a question on Stack Overflow
- I feel comfortable commenting on Stack Overflow
- I know how I'm supposed to post on Stack Overflow
- I feel that all of the easy questions on Stack Overflow have already been answered
- I worry that my question might be a duplicate
- I feel like my question is important
- I feel comfortable editing a question
- I worry that my posts will be harshly criticized by other users on the site
- I feel uncomfortable interacting with and relying on help from strangers online
- I feel intimidated by the large community of users
- I find it difficult to abstract away proprietary aspects before asking a question
- I feel like part of the Stack Overflow community
- I think figuring out unspoken social etiquette and community standards is too much work

[Chat about any strong agree/digress]

+ questions at the end:
- This mentorship exercise has been a positive experience
- This mentorship exercise has been a useful experience
- I would recommend this mentorship exercise to a developer friend
- I would participate in a mentorship exercise like this again

Open Response Questions
1. Did the mentorship meet your expectations? Why/not?
2. *[mentees only]* How would you describe your communication with your mentors?
3. *[mentors only]* How would you describe your communication with your mentees?
4. *[mentors only]* How would you describe your communication with fellow mentors?
5. What was the most important aspect of this experience to you?
6. Do you have any other thoughts or feedback about your experience?

[Stop the recording]

Thank you for your time and your help during this experiment.

B.3   Barrier Survey

Stack Overflow - Asking a Question

Thank you for taking the time to complete this survey. It should only take 5 minutes to complete.

We are researchers from Stack Overflow and North Carolina State University studying how software developers use Stack Overflow so that we can improve the experience.

For further questions about the study please don't hesitate to contact us: Denae Ford at denae_ford@ncsu.edu or Kristina Lustig at klustig@stackoverflow.com.

Please enter your Stack Overflow User ID.
How to find your Stack Overflow User ID: go to your profile and copy:
https://stackoverflow.com/users/7317251

Your answer

Asking a Question

You recently asked or began to ask a question on Stack Overflow, and in doing so went to a chatroom to receive assistance with asking your question. The following questions are about that experience.

Please rate your agreement with the following statements on a scale from 1 to 5, with 1 being strongly disagree, and 5 being strongly agree.

I feel that I am a part of the Stack Overflow community.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I feel more comfortable posting on Stack Overflow.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

The help that I received from this program was useful to me.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I would recommend this program to other Stack Overflow users.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I would like to participate in this program again.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

If you could change anything about this program, what would you change?

Your answer

Are you open to a brief discussion via phone or video chat about your experience participating in this program?

○ Yes

○ No

Please enter the best email address at which to contact you to schedule a time to talk.

Your answer

Do you have any additional thoughts or feedback for us about your experience asking a question on Stack Overflow? (optional)

Your answer

Thank you again for participating. Please contact us if you have any additional questions.

Page 1 of 1   SUBMIT

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C

CONTRIBUTION SIGNALS STUDY MATERIALS (CHAPTER 9)

This appendix includes the study materials of Chapter 9's `Contribution Signals` project. Stimulus presented to participants are available as webpages via my website.

C.1 Experiment Script

Experiment Script

Before Participant Arrival:
- The scheduled participant will have a participant ID number that will be used throughout the experiment.
- All tabs of the experiment must already be open. This includes Pre/Post Surveys, Implicit Bias Test, and 2 PR, 2 Profile pages.
  - Start participants on a blank desktop, allow them to take the Pre Survey [Calibrate on this page, **NOT A PULL REQUEST PAGE**]
  - Separate windows as shown below(this order helps provide a more natural switch between parts of study):
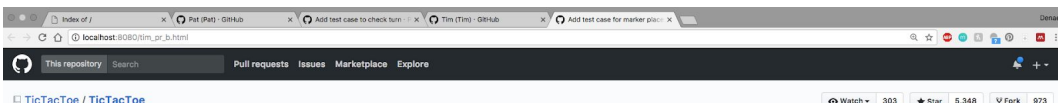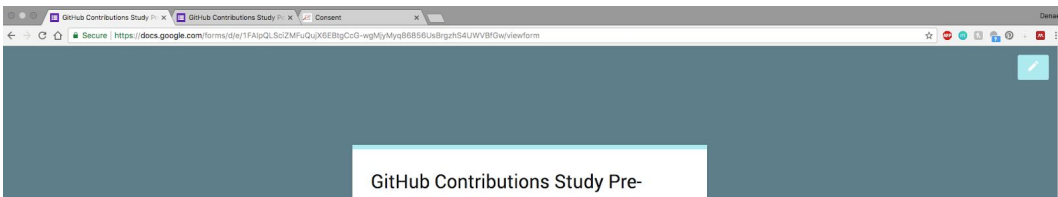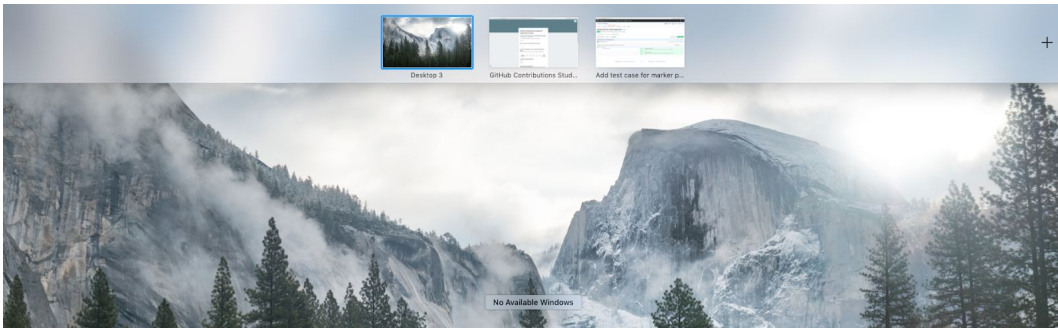
Instructions

1. Researcher will brief participant
    a. *Thank you for taking part in our study. This study aims at investigating signals programmers use when reviewing online code contributions. By using the collected data, researchers can implement more usable frameworks for safer and friendlier online communities for programmers to use.*

    This study does involve wearing eye tracking glass, so if you are not able to use glasses please let me know and I will stop the study.

    We will anonymize the eye tracking glasses recordings. As a reminder your identity will remain anonymous.

2. Researcher gives participant consent form to sign.
    a. *Here is the 2-sided consent form that you can read and sign. We can also provide you with a copy if you wish.*

3. Researcher prepares participant for Pre-Experiment Survey
    a. Researcher will select a computer for participant to use for the pre survey.
4. Explain the parts of the study:
    For this study you will be working on a TicTacToe Project with a team of developers. We will: play a round of tic tac toe to familiarize yourself with the rules for the game project, then review 2 pull requests based on Tic Tac Toe, next take an association test, and then participate in a debriefing interview.

    As a reminder your identity will remain anonymous throughout this study

5. Researcher will go over Tic Tac Toe for the grid [let them win]
6. Tic Tac Toe
    a. Explain how to win in Tic Tac Toe
    The important things to remember here is that to win you must place 3 of the same markers in a row.
    b. Play 1 round of Tic Tac Toe
    Another important concept to remember here is that each player takes turns and only one marker can go in a space at a time.
7. Researcher will perform 3 point-calibration of glasses
    a. *Now we will calibrate the eye tracking glasses for the study*
8. Researcher will turn on glasses recording(audio+video) + screen recording.
9. Researcher will begin experiment.
    a. Explain the task:
    For the next part, we will be reviewing pull request from project teammates.

For a quick refresher, pull requests let you tell others about changes you've pushed to a GitHub repository. Once a pull request is sent, interested parties can review the set of changes, discuss potential modifications, and even push follow-up commits if necessary.

For the next part of the study, I will show you a pull request and a corresponding profile page of teammates who submitted the request. We will give you time to look at each page and decide how likely you are to accept this pull request.

    b.   Scenario **[Repeat for Second PR]**:

[START RECORDING]

[Researcher opens <USER>'s profile page first].
You receive this pull request on your TicTacToe project from your teammate, <USER>.

This is <USER>.

Like many other users, <USER>, has had pull request accepted and rejected in the past.

You may select to view <USER>'s profile page if you wish. But for now we are going to look at their pull request.

This is their one commit of their pull request. We ask that you do not click any of the links in the page.

On a scale from 1 to 5 (1 being very unlikely and 5 being very likely), how likely are you to accept this pull request from <USER>?

When asked about signals say: "We are interested in whatever natural signals you use when you normally review code."
 [Note Answer in "Experiment Design" Sheet Of Participant Demographics]

[STOP RECORDING]

10. Researcher opens Post-Experiment Survey
11. Researcher prepares the Implicit bias Test-> click "Gender-Science IAT". Record participants score at end of survey and enter the response in the Debriefing Demographic Spreadsheet according to their participant ID.
12. Researcher will debrief the participant and enter the responses in the Debriefing Demographic Spreadsheet according to their participant ID.

a. *This will conclude our experiment. We want to thank you again for participating today. We have a couple demographic questions to ask you before you depart. As a reminder, your identity will remain anonymous. You can also refuse to answer any of these questions.*
  i. *What is your age?*
  ii. *What is your current gender identity?*
  iii. *What is your country of origin?*
  iv. *Do you identify as a minority in your country of origin?*
  v. *What is your current occupation?*
  vi. *Do you have any additional questions or comments?*
Please don't hesitate to contact us with any questions you have about the experiment. Thank you.

13. Fill in sheet for participant to receive credit for participating: [Extra Credit]

Citation for pull request description: https://yangsu.github.io/pull-request-tutorial/

C.2 Tic-Tac-Toe Materials

Tic Tac Toe

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)

(2,0)　(2,1)　(2,2)
(1,0)　(1,1)　(1,2)
(0,0)　(0,1)　(0,2)