Forming and Fulfilling Expectations: Perspectives of Underrepresented Computer Science Doctoral Students

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1 Introduction

In the field of computer science (CS), institutions are failing to produce enough computing graduates to fulfill predicted market demand. Not only is this the case at the undergraduate level [1], but also at the doctoral level, where educational institutions are unable to hire as many faculty as they need. As recently as 2017, a survey of 155 institutions found that 18% of the tenure-track faculty searches in CS failed to hire any faculty at all [2], indicating that not enough PhD candidates are pursuing faculty positions, at a time when a surge in computing course enrollments across the U.S. [3] requires more faculty than ever. In part, this may be due to the fact that PhD programs in computing have higher rates of attrition than other STEM fields [4]; not enough students are completing their doctoral program to meet the demand for faculty positions. In addition, women, persons with disabilities, and individuals from racial and ethnic minority groups are significantly underrepresented in CS at all levels [5]. This lack of representation among computing degree-holders exacerbates the challenge of producing enough computing doctorates to fill required faculty positions.

In this paper, we investigate the experiences of doctoral computer science students who self-identify as belonging to underrepresented groups (URGs). Our provided definition of students from URGs includes, but is not limited to, individuals from racial minorities (in computing), women of all races, people with disabilities, and individuals across a variety of gender and sexual orientations.[1] Understanding these perspectives is crucial to retaining students from URGs in doctoral CS programs and may offer insight into why the field fails to support and retain these students. Although we focus on this particular group of students, our findings can be used to support all PhD students in CS, and thereby enable more of them to complete their degrees.

Previous research shows that one key factor affecting the rate of degree completion among doctoral students is a clear understanding of what is expected of them in order to complete the program [6, 7, 8]. These expectations may concern requirements from the department or from a student's advisor, who has an important say in awarding a doctoral degree. We focus on two

[1]Participants were asked whether they self-identify as a member of a group underrepresented in computing, and this definition was provided as a non-exhaustive guideline.

kinds of expectations: what tasks the student is expected to complete, and how they are expected to complete them. The former category encompasses higher-level goals, such as the publication of a paper, while the latter focuses on the lower-level, daily tasks needed to complete the overarching goal, such as debugging the code being used in the publication. In this paper, we aim to investigate the different sources that students use to form their expectations, and how each of these sources provides different kinds of guidance.

To investigate these topics, our research team conducted a survey and semi-structured interviews with doctoral students from URGs at a large, Research 1 institution. This method of investigation was chosen given the exploratory nature of this work. In particular, conducting semi-structured interviews allowed us to gather student perspectives on a variety of issues that they considered to be relevant. In this paper, we present the analysis of the interviews. Our analysis finds that students had three primary sources from which they deduce what they are expected to do, and how to do it: research experience prior to beginning their program, their PhD advisor, and their peers. Each of these sources helps students understand different kinds of expectations, with advisors providing primarily high-level guidance on what tasks to accomplish, and peers helping each other with lower-level tasks. Many students began the program anticipating more hands-on support from their advisor, and instead found themselves relying more on their labmates and peers. We also find that students' initial expectations of what graduate school would entail did not always provide a complete picture, often giving them incomplete or inaccurate expectations. To address these issues, we suggest developing lab-based mentorship systems, and encouraging clear communication between advisors and students not only on high-level goals, but on the daily tasks needed to accomplish them.

2 Previous Work

Prior research has identified a number of factors that lead to doctoral program completion, many of which involve clear communication of student expectations. In a meta-analysis of 163 empirical articles regarding completion, achievement, and well-being in PhD education, Sverdlik et al. (2018) found that students' understanding of what their advisor (or supervisor) wanted them to do was an important contributor to student outcomes, with the authors noting that "open, supportive, and frequent communication with [their] supervisor was found to be essential for student success and satisfaction" [6]. Sverdlik et al.'s analysis also noted that poor communication of departmental requirements may lead to a discrepancy between the student's and the department's expectations of what the student needs to do [6]. Such a discrepancy can lead to the student insufficiently integrating into their institution and discipline, resulting in a decreased likelihood of degree completion [7]. In addition, clear communication of expectations may impact students in more ways than simply completing the program. For example, a survey of graduate students by Fisher et al. (2019) found that a clear understanding of their department's expectations contributed to lower levels of distress in women and minority (defined as Black, Latinx, and American Indian/Alaska Native) graduate students, and indirectly affected students' publication rates [8].

Apart from communication of expectations, much of the existing body of work on this topic has found that advisors are one of the most important factors affecting doctoral degree completion [6, 9, 10, 11]. The role of the advisor may be so important in shaping doctoral student experiences because they are the primary source for students' understanding of what is expected of them. In addition to helping set expectations, good advising has many facets: according to Posselt

(2018), successful advisors provide holistic support, with "academic, psychosocial, and sociocultural dimensions, which faculty enact through specific behaviors" [12]. This kind of supportive advising is not experienced by all doctoral students [7, 11, 13], and the impact of poor quality advising may differentially impact students from groups underrepresented in computing due to the discrimination they may face [14].

Doctoral attrition rates are generally higher in computing than other STEM fields, with computing having the lowest 10-year degree completion rate and highest attrition rate among STEM fields for students beginning their program in the 90s [4]. In addition to the already low number of PhDs awarded in computing due, in part, to high attrition, few of these degrees are awarded to students from URGs. The 2020 Taulbee survey found that only 21.7% of the PhDs awarded in computing by the surveyed institutions were earned by students who identified as women, and 13.4% of them by domestic students who did not identify as White [5]. Part of this disparity in doctoral degree attainment between majority and underrepresented groups may be due to the challenges students from URGs continue to face in higher education. For instance, Cohoon et al. (2011) found that computing graduate programs can feel unwelcoming to women, and their continued persistence in the face of adversity may depend upon the use of several coping mechanisms [15]. Students from URGs may also encounter a lack of supportive mentors [13], which may increase their likelihood of attrition. In a qualitative study of African American undergraduate and graduate computing students, Charleston (2012) highlighted the importance of mentors such as advisors in navigating challenges, noting that many participants "described how they considered withdrawing from computing science programs if not for the intervention of a mentor" [16].

Taken together, prior work not only suggests that computing doctoral students are less likely to complete their programs, but also that students from URGs face different and additional challenges compared to their majority[2] peers, which may further decrease their likelihood of completion. In this paper, we seek to better understand these compounded challenges by investigating how doctoral computing students from URGs understand what is expected of them and how to do it.

3 Research Questions

RQ1: How do students from URGs form expectations of their CS PhD programs?

RQ2: What sources do students from URGs rely on to form expectations of their CS PhD programs?

RQ3: How do students from URGs in CS PhD programs learn how to meet these expectations in order to complete their degree?

4 Methods

In order to answer the above research questions, our research team conducted a survey and follow-up interviews with Computer Science doctoral students at a large, Research 1 institution. Participants for the survey were recruited by soliciting doctoral students in the Computer Science department who identified as being part of an underrepresented community in computing. We chose to

[2]This refers to groups that are well-represented in computing, that is, White and Asian men.

recruit only students from URGs in order to highlight their voices and experiences. As a result, we do not have equivalent data from majority students, and thus do not make any comparative claims.

Recruitment occurred through email lists and a graduate student Slack channel. Our survey received 29 respondents, of whom 19 identified as women, and 14 identified as racial and ethnic identities other than White. After completing the survey, participants were invited to participate in an optional follow-up interview. In this paper, we discuss the findings from the resulting 14 interviews.

The interviews were conducted and recorded over Zoom due to the COVID-19 pandemic, and lasted no more than an hour. The protocol was semi-structured in nature to investigate participants' unique experiences and consisted of questions across three sections: the participant's relationship with their advisor, their expectations during the PhD, and their experiences learning and acquiring new skills in graduate school. A copy of the interview questions is provided in Appendix A.

Of the 14 interview participants, eight were in either the first or the second year of their PhD program. Table 1 provides a list of the pseudonyms used for our participants, along with their seniority within their doctoral program. Due to the relatively small number of individuals involved, we do not provide demographic or otherwise identifying information about the interview participants.

Early stage (1st or 2nd year)	**Middle to late stage (3rd year+)**
Anthony	Anna
Glen	Diane
Kurt	Hannah
Mia	Patricia
Nora	Robert
Phoebe	Tom
Tracy	
Yvonne	

Table 1: The interview participants by degree seniority, using researcher-assigned pseudonyms.

After all of the interviews had been completed, the audio recordings were sent to a third-party service to be transcribed. These transcriptions were further reviewed by the authors to remove any identifying information. The authors then analyzed the anonymized transcriptions using a qualitative coding process. Due to the exploratory nature of the work, coding was conducted inductively, with no codes determined a priori [17]. Each team member independently coded one of the interviews in order to identify initial key ideas and themes. A preliminary codebook was developed based on these observations and used to code the remaining interviews. The authors met regularly during the coding process in order to continue iterating on the codebook, adding and removing codes as necessary, and resolving any conflicts or confusion regarding the application of the codes. At the end of the first pass of coding, the authors listed and discussed findings relating to themes and variations observed in the data. In this paper we discuss only those findings which are relevant to our research questions regarding expectations. A second round of coding was conducted on the subset of codes relevant to this paper in order to ensure all evidence regarding the findings of interest to this work had been identified.

5 Results

We highlight that the results presented here are a subset of our findings, restricted to those that pertain to forming and fulfilling expectations. Within this scope, we find that participants did not typically refer to experiences specific to their social identities when discussing expectations.

Our analysis identified three key sources from which students appear to form their expectations: students' prior research experiences, their PhD advisor, and their peers in the doctoral program. Notably, each of these sources provides different types of support and advice.

In the quotes used in this section, we have used square brackets (i.e., [added text]) to indicate words added for clarification, and three dots (i.e., ...) to indicate a removal of text.

5.1 Prior Research Experiences

Mentors and peers from before graduate school help shape expectations. Many participants reported engaging in research experiences prior to attending graduate school. During these research experiences, some participants encountered key mentor figures and peers that often formed their expectations of what graduate school would look like. For instance, when Anthony was asked about the source of his expectations for what he "should be doing" in graduate school, he discussed attending conferences as an undergraduate, and observing the graduate students "not only attending, but also actively involved in making some contribution, or organizing." Anthony went on to describe treating these individuals as "kind of a role model," indicating that he adopted these behaviors as a blueprint for what to do during the doctoral program and how to be "active" in the research community. Similarly, Mia reported that the professors at her undergraduate institution formed her view of what graduate school would look like, providing advice regarding "what you need to do in order to be successful in a PhD program." In Mia's case, mentors from her prior experience not only helped her understand what she would need to do in graduate school, but also shaped her perception of what success in the program might look like. Most of our participants discussed engaging in research before entering graduate school, and it is reasonable for those interactions to form their initial expectations regarding what they would need to do in a PhD.

Prior expectations can be incomplete. Despite these prior experiences, many participants reported being surprised by aspects of research once in graduate school. For instance, a few participants discussed being surprised by the importance of writing and presenting the results of a study, and the relative lack of focus on programming. As Patricia explained, "it's not the system you build that is the big part of the research, but it's after when you get the results back." Phoebe realized that time management during the PhD was more challenging than she had anticipated. She expected coursework to play a minimal role in the degree program, but found instead that it was difficult to balance both research and coursework. For many students who felt that they knew *what* needed to be done coming in, learning *how* to complete those tasks still felt challenging. Yvonne struggled to find a compatible advisor, and felt that although it was clear that finding an advisor was important, there was little guidance on how to go about it. She reflected that, in retrospect, it would have been better to have a particular advisor in mind before applying to the program. Thus, in Yvonne's case, even though she came in with expectations of graduate school based on prior experience, these expectations were incomplete, helping her understand what needed to be done, but not how to do it.

5.2 Advisors

Advisors tend to provide high-level guidance. Once in the PhD program, students often based their expectations of what to do on the recommendations of their advisors, particularly regarding what big-picture steps to take to complete their degree. Most participants indicated that their meetings with their advisors took place at an abstract level, discussing research directions, status updates, or degree progress, and that they received advice on how to proceed on those topics. For example, Tom described their meetings as including "career advice, internship advice, and just general research things," highlighting that he primarily received advice on the big-picture goals he needed to pursue. Discussions of what to do in the PhD often operated on the same level: for instance, when asked what his advisor expects him to achieve during the degree program, Kurt responded that his advisor's expectations are "totally the same requirements as the department's to obtain the PhD. Pass the qual exam, do your thesis." Another student, Robert, described his advisor "more like a sage rather than a teacher," explaining that the kind of guidance he received from his advisor did not help him understand how to do research on a daily basis. Milestones and advice of this kind represent a clear expectation of what the student needs to do, such as publish a paper or pass an exam, but does not necessarily inform students how these tasks are accomplished.

Advisors expect students to "figure it out on [their] own." Although their respective advisors guided our participants towards the milestones they were expected to achieve, most of our participants indicated that their advisor did not help them solve lower-level, everyday issues. Only two of our participants indicated that their advisors had helped them debug code; most of the others described their meetings as covering only big-picture topics. In fact, Glen reports that after the first few challenges, he realized that his advisor "really didn't have time to actually get into weeds to help me out with something." The relative independence advisors expect from their students seems to have been a surprise to some of our participants. For example, Patricia says that she came in thinking that she would be assigned to work on an existing project, but instead found that "it was my job to figure out a research idea and then work on that." Her advisor was willing to guide her, but was "pretty hands off" when it came to understanding what she needed to do on a daily basis. Patricia, and other participants reporting similar experiences, had to find a different source to help them understand the steps required to conduct research, such as identifying a focus or debugging code.

Advisors recommend asking peers for help. Of the participants that mentioned that their advisor did not have time to help with low-level issues, many noted that their advisors usually suggested talking to a labmate in order to resolve the issue. Diane describes her advisor pairing her with a senior PhD student in her lab as a first year in order to work on her first project, and describes the senior student as "sort of like a mentor." This mentor-like relationship includes relying on the senior student for feedback and on project ideas and "general grad school things... like housing." Both through the recommendation of their advisor and their own initiative, many of our participants relied on peers' help in the PhD program, as discussed below.

5.3 Peers

Students often reach out to peers for help. Interactions with peers were another key source from which students formed expectations and understood how to fulfill them. Participants generally referred to other students in the same lab as the peers they turned to for help. These instances of

asking for help came both from their own initiative and from their advisors suggesting that they ask a labmate for help. For instance, Glen describes seeking out advice from his senior labmates about his timeline for achieving a PhD, and finding out that he "should probably get a paper by my second year." This piece of advice highlights peers' ability to help convey *what* students need to do, not just the how. Glen added that he felt more comfortable talking with other graduate students who had similar experiences instead of his advisor who always seemed busy. In addition to receiving such high-level advice, students often sought out peers for more lower-level help. When planning out her thesis, Anna reached out to former labmates who had graduated for help in how to organize it, and asked for copies of their theses to read. By doing so, she was able to develop her thesis structure without relying on her advisor. In another example, Nora notes that when she asked her advisor for help with a new concept, he suggested that she reach out to one of his other students who had experience with the tools she needed. Nora and Anna are both examples of cases where peers were able to help our participants figure out *how* to achieve a particular task.

Observing peers can help students form expectations. Although many students reported actively seeking out peers for help, it is also worth noting that many of them formed expectations for graduate school simply based on their observations of other students. These expectations often concerned the high-level goals students felt like they ought to be achieving. For example, Anna recollects that she felt pressured to publish more after "seeing how often they [peers] publish," and that this was a source of her "standards" for how much PhD students should publish. Other participants similarly mention using other students' research output and behavior as a comparison to their own. Hannah also describes that she better understood what kind of work graduate school entails by observing her peers, although these expectations did not necessarily concern a task required to complete the degree. She notes that after some time in graduate school, her understanding of what research work in academia looked like "really comes down to my peers and what I see them working on." The result was that "the vision that I had at the beginning of what academia would be like didn't really live up to what it actually was for me, anyway." Observing her peers allowed Hannah to form a clearer picture of what academia looked like, and in her case, that it was something she did not want to pursue further. The phenomenon of students using peers' work as a tool for comparison and clarification highlights the importance of peer relationships in graduate school, as they are the first source students turn to when expectations from other sources are not clear enough.

6 Discussion

Our research questions aimed to investigate how students' expectations of a PhD program are formed, what sources they tend to rely on to form these expectations, and how they learn to meet them. We are interested in expectations of two kinds: expectations surrounding *what* work they will do, and *how* they will do it. In the first category, we include discussions around what goals they need to achieve (e.g., a publication, qualifying exam) in order to complete the degree. The second category describes the actions students must take to achieve these goals, such as building software or writing the results of a study. Although students' own definition of success plays a role in determining expectations, we narrow our definition here to tasks needed to complete the degree.

One key finding from our work is that among our participants, although they used their prior research experience to form expectations of the program, their experiences did not fully or accurately reflect what graduate school would look like. This finding is especially worth noting given that our participants attend a highly-ranked CS PhD program, and had prior research experience that made

them competitive enough to be admitted. Despite this, they expressed surprise about aspects of research in graduate school. In particular, our participants were surprised by the daily work that goes into research, such as the amount of writing and the time-management required. It is possible that the surprise our participants felt is because undergraduate research experiences do not aim to perfectly prepare students for graduate school, but rather give an introduction. However, prior research experience is highly valued in the PhD admissions process, which may be why students were surprised to find that previous research did not give them accurate or complete expectations of the doctoral program. This highlights the importance of advisors and students needing to calibrate their expectations together, rather than assuming prior experience will provide a complete picture.

Our results further suggest that students encountered more obstacles in understanding *how* to accomplish a particular task, rather than understanding what they needed to do. Some participants felt that they did not have enough support in how to do the things required of them, such as finding an advisor. These findings imply that clear communication between students, advisors, and the department requires not only stating what the goals are, but also providing step-by-step support to students in achieving that goal.

Another major contribution of our analysis is to emphasize the importance for students to have a support network. As discussed above, advisors tend to provide guidance at a high-level, and often do not have the time to "get into the weeds" with each of their students individually. Therefore, advisors may attempt to redirect their students to other resources, such as more senior students in their lab. This allows students to expand their support network and learn the independence needed to succeed in graduate school. In addition, even when advisors do not direct students to do so, we find that they often choose to turn to their peers for help anyway. Taken together, these results may point to the need for students to be able to support each other with smaller-scale issues in a systematic way, so that they do not have to spend time searching for those relationships themselves. In particular, advisors could create a mentoring system within their labs, wherein senior students support their more junior labmates. This may be beneficial in developing the support structure a newer student may need without relying solely on their advisor. Such a mentoring system has the added benefit of helping those students who are more comfortable talking to their peers than their advisor, and providing each new student with a designated mentor to ask for help, rather than wondering who to talk to. Given the qualitative nature of our study, we acknowledge that additional work is needed to further explore such a recommendation.

7 Limitations & Future Work

Our work is limited in a number of ways. First, it is worth highlighting that this work was conducted with students currently attending a highly-ranked program and institution, meaning that they are all highly-qualified and experienced, and likely to have had more access to research opportunities before graduate school. In addition, since they are persisting in the program, we do not know what factors may affect students' decisions to leave their programs, which may be a possible avenue for future work. Further, we had a relatively small number of participants, where a majority of them were early-stage PhD students (eight out of 14 were in their first or second year), and experiences of students later in the degree progression are not as well-represented. While there is a heavy focus on early-stage students, we note that the early years are a key period during which students transition to and become socialized within PhD programs, and are thus of particular interest in understanding how their expectations are formed. We also note that for these

early-stage students, a majority (if not all) of their experience in graduate school has occurred during the COVID-19 pandemic. This has likely impacted their interactions with their advisors, peers, and the department. One possible avenue for future work would be to conduct a longitudinal study, encompassing the changes in perspectives students may undergo over time, in order to better understand how their expectations may have changed throughout their graduate school career.

We also note that students' expectations of themselves are likely to be interwoven with their own perception of what it means to be successful in graduate school. For this reason, we have chosen here to focus primarily on expectations that relate to requirements set by either the department or the advisor, as these connect directly to degree completion. However, it is difficult to separate which expectations stem from the advisor, and which of them are impacted by the student's own sense of what they need or ought to accomplish. In the same vein, it is conceivable that students' expectations of themselves are affected by their background and their social identities. Future work studying this question can engage specifically with the question of how students conceptualize success, whether this connects to aspects of their identity, how this conception interacts with their expectations of what they need to do, and how these notions may change over the course of the degree program.

A final limitation we wish to acknowledge is that the members of the research team identify as belonging to URGs themselves, and were also familiar with some of the participants. This may affect our analysis in ways we cannot accurately measure.

We focused the sample and analysis of this paper on student voices, in particular students from URGs, in order to highlight their voices and identify strategies that can be used to support these populations and benefit all graduate students. However, a more complete picture of the graduate school experience requires an understanding of the perspectives of the department and the faculty. In addition, our analysis does not identify experiences unique to students from URGs, as this would require equivalent data from majority students. While this was not the aim of this study, we believe future work in this area can investigate how expectations are being communicated from the department and faculty perspective, as well as the experiences of majority students.

8 Conclusion

Our study sought to investigate the experiences of students from URGs in CS PhD programs and to better understand how they determine what is expected of them in order to complete the program. We were interested in what sources students rely on to form these expectations, as well as how they learn to meet them. We limited our work to those goals which were necessary in order to complete the degree, which includes tasks set by the department and by the student's advisor. Understanding how students from URGs form and fulfill expectations is particularly important in the field of computing, where attrition rates are higher than those in other STEM fields, and not enough of the PhDs awarded are given to students identifying as underrepresented in the field.

In our investigation, we found that our participants had three primary sources from which their expectations were formed: prior research experience, their PhD advisor, and their peers in the degree program. We find that students receive different types of expectations from different sources, with advisors primarily helping them understand what their big-picture goals should be, and peers helping them with smaller research tasks. However, we also find that students were surprised by certain aspects of how graduate school differs from their research experience as an undergraduate, including the experience of their advisors being available mostly for high-level support. To address

this issue, we suggest that clear and successful communication between students, advisors, and the department should include not only what goals the students need to achieve, but also support on how to achieve them. Developing a lab-based mentorship system, where more senior students can provide lower-level help to their junior labmates, may also be one mechanism by which to provide such support.

This work leaves open several possible threads for future research. In particular, the research team hopes to investigate how students from URGs in computing PhDs define success, how their expectations are affected by their definition of success, and how these expectations may change over the course of their degree.

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Appendices

A Interview Questions

A.1 Introduction

- What year in your PhD are you? What kind of research do you do?
- What made you pursue a graduate degree?

A.2 Advisor Relationship

- How often do you meet with your advisor? What is the format of these meetings? (E.g. status updates, big-picture discussions about your degree progress, help with debugging)
- How has this changed during the pandemic?
- Do you talk about non-academic things? E.g. things happening in the world, things happening in your lives?
- In what ways does your advisor try to make your lab/research group an inclusive space?
- In what ways do you think aspects of your identity have affected your interactions with your advisor?
- Have you ever had to discuss mental health issues with your advisor? If so, how did that go?

A.3 Expectations

- Are there differences between what you expect to achieve during your PhD, and what your advisor expects?
- What would you say is the source of your expectations? (E.g. parents' graduate degrees, meeting grad students in undergrad, movies/books)
- Have any of the things you are expected to do during the PhD surprised you? (E.g. didn't think I would be expected to get a publication every year)
- What do you think it means to be a "good researcher"? How does this compare to how your advisor defines it?
- How do you work towards becoming a "good researcher"?
- Are there differences in how you measure your own progress and how your advisor does the same?
- Have these "standards" changed over time, e.g. during COVID?

A.4 Learning/Acquiring Skills

- In what ways has your advisor helped you pick up new skills, such as teaching and research?
- Did they point you to specific resources?
- If not, how did you first learn about these resources?

A.5 Conclusion

- Is there anything else regarding your experience as an underrepresented CS PhD student that you would like to bring up?