Student Belonging in Teaching Assistant Interactions and Course Policies in Post-Secondary Computer Science

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Abstract

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All students studying Computer Science (CS) deserve to have their basic psychological need for belonging satisfied. In this dissertation, I present two studies of belonging among CS students at the University of Washington Paul G. Allen School of Computer Science and Engineering. In the first study, my collaborators implemented a resubmission policy in introductory CS courses. My collaborators and I ran a large-scale, end-of-term survey asking students about their reasons for resubmission. We then interviewed nine students about the resubmission experience. In the second study, I studied students and teaching assistants (TAs) in 4 CS courses, including introductory, intermediate, and advanced; core and elective, interviewing them about their belonging in post-secondary CS. I conducted semi-structured 1:1 interviews with 14 participants, consisting of 7 pairs of students and TAs who interacted in office hours. I found that given the Allen School's competitive program, resubmissions take the pressure off the need to submit work that earns a perfect grade the first time, and that belonging may exist alongside preparatory privilege in some students. Nevertheless, my findings suggest that resubmissions alone can't create space for belonging, but that collaboration and relationships can. However, organic collaborations were inhibited by a strong fear of risking academic misconduct. I also found that student and TA conceptions and narratives of belonging aligned with the three basic needs for wellness as described in Self-Determination Theory: relatedness, competence, and autonomy. TAs and students reported that TAs supported student sense of belonging by fostering understanding of material, treating them with empathy, helping them see peers positively, and helping them to own their own success. Therefore, I claim the following thesis statement: In post-secondary computer science, both course policies and direct interactions with instructors and peers can contribute to the satisfaction of psychological needs for competence, relatedness, and autonomy, which can contribute to student sense of belonging.

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To all my teachers and all my students, past, present, and future.

Chapter 1

INTRODUCTION

Belonging has long been established necessary toward thriving in organizations, communities, and learning settings. Fundamentally, belonging is a basic human need [9, 49]. It is important in school [31, 78, 25], and it drives motivated behavior [20], including at school [32, 31].

Computing education is no different; prior work on post-secondary shows that peers matter, culture matters, and content matters, especially for students from marginalized groups. For example, peer relationships are connected to performance [79] and career choice [69]. Peer relationships especially matter for students from groups marginalized in CS [69, 65]. When it comes to culture and climate, perceived culture of CS influences belonging [43], climate relates to the formation of hierarchies among CS students [8], and even physical environments influence student interest in CS along gender lines [17]. Culture and belonging contribute to a structural pattern of retention in CS: those who feel they belong choose to continue, normalizing the culture that filtered for them in the first place [80]. Teaching students about inclusion itself can make a difference for retention [45, 80].

In this dissertation, I focus on two facets of the student experience: grading policies and TA (teaching assistant) interactions with students. While many phenomena can affect belonging, these two are among those that instructors can directly control, both are highly influential for students, and neither has been deeply studied with respect to the specifics of its impact on student belonging. In a context like the Allen School, the lead instructor has little individual contact with each student, while supporting instructors, namely TAs, have the majority of contact hours and individual interactions. Grades are a significant part of the student experience because CS students use them to assess their CS ability [44] and employers use them to decide who to interview for programming jobs.

Prior work suggests that both grading and student interactions with TAs may be important towards belonging, but lacks evidence from student perspectives to establish the specifics of how each of these phenomena influences student experiences of belonging.

Emerging work suggests that TAs may be of particular importance. For instance, in a study examining TAs acting as community facilitators, students reported a greater sense of community [4]. TA behavior can play an important role in shaping where students get help with programming problems [41]. Having "relatable" TAs and TAs as mentors are inclusive factors for women of color in CS [75]. However, prior work has not yet examined the specifics

of how TA identity and behavior shape student belonging.

Based on prior work, the ability to revise grades through resubmission opportunities might be expected to influence a student's sense of belonging. Other people's perceptions are an important component of belonging [47] including in post-secondary CS [52], so for students who perceive their grades as signalling an instructor's perception of them as a person (regardless of whether the instructor intended it that way), resubmission opportunities could give a student more chances to feel accepted and thereby develop a sense of belonging. As another possible pathway, in post-secondary CS, resubmission opportunities are linked to self-efficacy [73] and self-efficacy is linked to belonging [79]. However, I am not aware of prior work that connects belonging in CS directly to resubmission opportunities.

In this dissertation, I put forth the following thesis:

> In post-secondary computer science, both course policies and direct interactions with instructors and peers can contribute to the satisfaction of psychological needs for competence, relatedness, and autonomy, which can contribute to student sense of belonging.

I demonstrate this thesis across two chapters, one examining how assessment policies interact with belonging and one examining how TA behavior interacts with belonging.

Chapter 2

BACKGROUND

2.1 Theories of belonging

Many varying but interrelated concepts of belonging exist across and within disciplines. Mahar et al. review trans-disciplinary concepts of belonging [47]. One example is the Hagerty concept of "general" belonging, measured by the widely used Sense of Belonging Instrument (SOBI) [34]. This instrument defines belonging as "the experience of personal involvement in a system or environment so that persons feel themselves to be an integral part of that system or environment," including two distinct attributes of sense of belonging: "valued involvement or the experience of feeling valued, needed, or accepted" and "fit, the perception that the individual's characteristics articulate with the system or environment." Goodenow presents an alternative definition a learning context as "sense of being accepted, valued, and encouraged by others... feeling oneself to be an important part in the life and activity of the class" [32]. This work has been widely used in schools, including at the post-secondary level, to measure belonging with the *Psychological Sense of School Membership* (PSSM) scale [33, 25, 62, 61].

Some work links belonging to fundamental human needs. For example, Bauminster's "belongingness" hypothesis posits belonging is a basic human need [9], and has linked it to theories of human need hierarchies, such as Maslow's [49], which put needs like belonging as less important than other more basic needs, such as physiological and safety needs. Other models of human needs are flatter, but still place social needs such as belonging higher than physiological needs [30, 31]. In models of human motivation, belonging features as a component of key needs that motivate behavior [30, 31, 20]. Work on belonging in human needs finds that while internal thoughts can affect the person's belonging [3], things outside of a person are just as important [13]. For example, Josselson describes 8 dimensions of the human need for "relatedness," including "embeddedness" which is "to be embedded within a social network is to feel included, to share characteristics, to be the same as, to give up some individuality in the interconnection... embeddedness implies a sense of belonging" [37, 38].

Theories of belonging in post-secondary education often relate belonging to student adjustment and retention in post-secondary institutions [71, 2]. For instance, according to Tinto's institutional departure model, students must be integrated socially and academically into their college environment, otherwise it could lead to departure [78, 2]. Belonging to

one's institution and belonging in a certain classroom are two separatable concepts [25]. Belonging in a classroom is associated with academic self-efficacy, intrinsic motivation, how much students value class activities, and perceptions of their instructor, whereas institutional belonging is associated with social acceptance [25].

The macro-theory of *Self-Determination Theory* (SDT) ties together ideas from other theories about belonging and human psychological needs. SDT identifies three basic psychological needs: *competence*, "to engage optimal challenges and experience mastery or effectance in the physical and social worlds," *relatedness*, "to seek attachments and experience feelings of security, belongingness, and intimacy with others," and *autonomy*, "to self-organize and regulate one's own behavior"[20]. When these three needs are satisfied, one can experience psychological wellness and autonomous motivation [20]. SDT places belonging as a subcomponent of the need for relatedness [20]. However, colloquial concepts of belonging could connect more expansively to different concepts within SDT. For example, when asking a student "do you feel like you belong in computing," they could interpret it as "are you able to perform highly and succeed in computing" [79] (competence), "is everything ok for you in computing" (psychological wellness), or "do you want to keep studying computing" (autonomous motivation). Therefore, I draw on all these concepts from SDT to inform qualitative analysis in my work.

2.2 Belonging in CS

Prior research on belonging in post-secondary CS education has mostly not drawn upon particular theories, but has revealed empirical patterns consistent with the theories above. For example, some prior work on post-secondary CS defines belonging as how students see themselves in relation to their ability to perform or succeed in the discipline [79], to the objects in the environment [17]; to the peers "imagined to occupy the environment" [17], to how they perceive others see them [52], to how they feel welcomed [79] and to how they feel valued [52]. Notably, the concept of CS *ability* appears explicitly in post-secondary CS education literature on belonging. Since an academic environment centers on students building knowledge, and since a defensive climate, in which students form social hierarchies based on their knowledge, is prominent in CS environments [8], this could be understood as a discipline-specific example of the more general idea of "fit" with the environment and with others.

Prior studies of belonging in post-secondary CS reveal many factors shaping it [68]. Physical objects in an environment can have a gendered impact on belonging [17]. A student's culture and the culture of the CS academic space can also impact belonging [43, 8, 26]. Peers, academic performance, and self-efficacy all interact to impact belonging

[79]. Peer relationships are especially important for students from marginalized groups in CS [69, 65]. Belonging and persistence in computing connect to social power structures of race and gender; many inclusion interventions ignoring these power structures have failed [65]. Faculty may teach students about issues affecting marginalized students [80] or alternative narratives to stereotypes about computer scientists [45] in an attempt to impact their sense of belonging, and, more broadly, elements of computing culture that shape belonging. Participation in networking, outreach, and mentoring may raise belonging for women [52].

Studies of post-secondary CS also demonstrate how Self-Determination Theory's themes of competence, relatedness, and autonomy interact with belonging. For example, a sense of belonging in academic peer groups and non-academic communities of academic peers or family can help students perform better in course work (competence) [79]. Peer relationships (relatedness) are associated with performance (competence) [69]. And interventions to increase student autonomy can improve engagement, performance, interest, self-confidence, and belonging [16].

2.3 TAs and belonging in CS

Prior work establishes the important role of TAs is belonging, but the mechanisms of their impact are not yet well examined [51]. Most prior work has been from an instructor and managerial perspective, examining how to support TA professional growth [39, 72, 58], how to structure TA management and retention programs [22, 63, 21, 57], how to leverage TA efforts to facilitate learning and student retention [11, 12, 14], and TA training [66, 50, 23, 5]. Only a handful of works examine TA perspectives, studying peer tutoring [48] and pedagogical challenges [67], but these do not address student belonging.

Recent prior work not explicitly about belonging has shown indirectly that TAs contribute to belonging. In work by Kuperwajs-Cohen, CS1 students reported that factors such as judgment, intimidation, familiarity, and trust impact their decisions to get academic help from sources including their TAs [41]. Work by Tari et al. on experiences of Asian and Pacific Islander experiences in CS [75, 76, 77] showed that TAs' identities and behavior impact CS students' belonging, with TAs particularly lamenting lack of guidance on supporting students from underrepresented groups.

While the substantial prior work on belonging in CS and in general establishes that TAs shape belonging, prior work has not yet examined how TA identity and behavior does this shaping.

2.4 Alternative grading and belonging

Alternative grading models propose to improve upon traditional grading, often incorporating resubmission opportunities. Mastery learning models aim to offer instruction according to each individual student's needs, so that even if initial aptitude is thought to be normally distributed across a class, the end result can be a "uniformly high level of performance for all" [40]. Individual instruction could come in the form of tutoring from an instructor, or the student's own self-paced study of written materials. Some models of mastery learning involve students retaking assessments until they demonstrate mastery [40, 54, 42]. Contract grading focuses on providing students with clear, well-defined criteria for achieving a desired grade at the time an assessment is released. These criteria do not depend on external factors (such as the performance of other students) and therefore allow students to set a target grade and understand what is required to achieve that grade [54, 42]. Specifications grading takes the ideas of contract grading further by limiting grades on an individual assignment to pass or fail, evaluating students simply on whether or not they met the requirements of the specification [53].

Alternative grading models with resubmission opportunities in post-secondary CS have been evaluated on the basis of student performance, engagement, and experiences. Resubmissions can raise grades compared to if the student had not resubmitted work [81, 27, 42]. However, allowing students to work at their own pace as they resubmit work until they succeed takes away the structure provided by deadlines, and engagement may decline for students who are not self-regulated learners [54]. Grading systems with resubmissions have been well-received by students as useful for learning [81, 27, 42], but critiqued for not giving points for effort [81]. In some implementations, students feel more in control of their grade as compared to traditional grading that they have experienced [42], but in some cases the calculation of the final grade can confuse students [81].

Prior work establishes links between resubmission opportunities and self-efficacy, and between self-efficacy and belonging. Self efficacy is a person's belief in their ability to succeed [6]. According to Bandura's principle of *enactive attainment*, success in a specific situation increases self-efficacy for similar situations [6]. What constitutes "success" is subjective, but resubmission opportunities in college STEM[1] courses connect to measures that could be seen as contributing to success, including attainment of higher grades, learning, and improving one's work [18, 81, 27]. Indeed, recent work presents evidence of a connection between a grading system that offers resubmission opportunities in a post-secondary CS course and higher levels of student self-efficacy [73]. Self-efficacy is connected to belonging [24, 28], including in a post-secondary CS setting [79]. While prior work hints at pathways by which

[1]Science, Technology, Engineering, and Mathematics

resubmission opportunities could potentially increase belonging, I am not aware of prior work that directly connects resubmission opportunities to belonging in post-secondary computer science.

Chapter 3

READING BETWEEN THE LINES: STUDENT EXPERIENCES OF RESUBMISSION IN AN INTRODUCTORY CS COURSE

In this chapter, I describe an alternative grading system implemented in introductory computer science courses in the Paul G. Allen School of Computer Science and Engineering at the University of Washington and a survey and interview study to evaluate the system. I conducted the work in this chapter in collaboration with Jayne Everson, Ken Yasuhara, Brett Wortzman, and Kevin Lin.[1] [2] [3]

Motivated by the need to develop computer science identity (CSID), and sense of belonging in introductory computer science, we implemented a resubmission policy in our introductory CS courses. We ran a large-scale, end-of-term survey of all students across two large introductory CS courses asking about their reasons for resubmission. Many responses suggested intrinsic motivation, with over half the students mentioning improving or completing their work among their reasons for resubmitting, but we also found about a third of the students citing higher grades as their only reason. We then interviewed nine students about the resubmission experience. We found that given the Allen School's competitive program, resubmissions take the pressure off the need to submit work that earns a perfect grade the first time, and that CSID and belonging may exist alongside preparatory privilege in some students. However, our findings suggest that resubmissions alone can't create space for CSID and belonging, but that collaboration and relationships can. Furthermore, organic collaborations were inhibited by a strong fear of risking academic misconduct. The results of this study connect to SDT in that some of the experiences students described when talking about the resubmission policy and about CSID were experiences of competence, relatedness, and autonomy, the three basic needs of SDT.

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[1] I use the term "we" in this chapter to acknowledge the shared contribution of all authors.

[2] I wish to thank Hunter Schafer and all the students who participated in the study.

[3] We presented this work as a poster at the 2022 Technical Symposium of the ACM Special Interest Group on Computer Science Education (SIGCSE '22), and an extended abstract version of this chapter is archived in the proceedings of that conference [59]. This chapter is based on a manuscript we submitted as a conference paper to SIGCSE '22.

3.1 Introduction

Mastery learning models propose to tailor instruction to student needs so that all students can achieve high performance, regardless of their starting point [40]. One feature of mastery learning models is allowing students to resubmit work until demonstrating mastery [40].

Mastery learning models may be implemented in tandem with alternative grading practices. One practice is to replace multi-interval grades (such as A, B, C, D, F) with a written feedback [15]. Some educators replace multi-interval scales with a simpler *pass* and *fail* [10]. Instructors may enumerate grading criteria to ensure that a student's grades are based only on their own performance (and not the performance of other students, as in "curving") [42]. To establish criteria for final grades, instructors may count the number of assignments completed at a certain level rather than averaging together assignment scores [73, 81, 74]. Different instructors combine mastery learning and alternative grading practices in different ways. For example, Talbert's *specifications grading* model incorporates 2 and 4 level grading scales for each assessment, final grades calculated based on how many assessments were completed at a certain level, and clear critera for earning each grade, and a limited number of resubmission opportunities [74].

Implementations of mastery learning and alternative grading with resubmission opportunities in post-secondary CS have helped raise performance and have been well received by students [27, 42, 81].

Resubmission opportunities might be expected to support student sense of belonging, both because of how grades may be seen as an instructor's perception of a student, and because resubmission opportunities are linked to self-efficacy [73] and self-efficacy is linked to belonging [24, 28, 79]. However, I am not aware of prior work that connects belonging in post-secondary CS directly to resubmission opportunities.

We introduced a resubmission system inspired by Talbert's model of specifications grading [74] in programming courses enrolling over 1,400 students in total across two academic quarters. We awarded final grades according to the number of satisfactory assignments done by the end of the quarter. Grading was additive and monotonically increasing: submitting work never reduces a student's grade.[4] Smaller assignments were graded either satisfactory (S) or not yet (N), while larger assignments were graded on an expanded, 4-level ESNU scale: exemplary (E), satisfactory (S), not yet (N), unassessable (U). In some courses, larger assignments received multiple ESNU grades: one for each of several grading categories. This simplified grading scale was designed to reduce anxiety over "losing" points on submissions and instead focus student effort toward mastery of learning objectives. After making an

[4] In 2021 winter, P1 and P3 used a policy saying that grades *may* go down after resubmission, but the authors are not aware of any student's grade actually falling.

initial submission, students were encouraged to revise and resubmit unsatisfactory work throughout the quarter.[5]

To understand the impact of our new grading practices, the following research questions emerged.

- RQ1: What reasons do students choose for resubmitting?
- RQ2: What is the resubmission experience like for students?
- RQ3: In what ways do resubmissions make space for students to belong?

3.2 Resubmission system

Our resubmission system and grading system took ideas from many of the approaches above, especially following the example of Talbert [74]. One value from mastery grading that we hoped to embody with this grading system was producing final grades that represented what a student *knew* at the end of the course, rather than the mistakes the student had made in the process of learning. The key elements of our implementation were:

- Smaller assignments were graded either satisfactory (S) or not yet (N), while larger assignments were graded on an expanded four-level ESNU scale: exemplary (E), satisfactory (S), not yet (N), unassessable (U).
  - In some courses, each submission received a single grade on the ESNU or SU scale.
  - In other courses, larger assignments had several grading dimensions, and each submission received multiple ESNU grades, one for each dimension.
- Generic rubrics with expectations for each grade were published to students, though detailed interpretations of the generic rubric for individual assignments were kept internal.
- Written feedback was provided along with grades for all student work.
- Students were allowed to resubmit work after initial feedback had been received. Students could resubmit each assignment as many times as they chose, but resubmission opportunities were limited to one per week, to manage grading workload for teaching assistants.
- Final grades were assigned based on "bundles" of grades achieved on work throughout the quarter. Minimum requirements for certain grade cutoffs were published at the start of the term. Actual final grades were determined by the course staff at the end of the term, but did not violate these minimums.

Table 3.1 lists the Allen School courses that used this resubmission system in autumn 2020 and winter 2021, the academic term each was offered, and the professor teaching.

[5] In this chapter, I use the term "resubmissions" as a metonym to refer to the entire grading system for the courses in the study.

Course	Term	Prof	Survey	Interview
CS1	2020 autumn	P1	✓	✓
CS2	2020 autumn	P2	✓	✓
CS2	2021 winter	P1		✓
Data Programming 2	2021 winter	P3		✓
Data Structures and Algorithms	2021 winter	P2		✓

Table 3.1: Courses with Resubmissions

3.3 Methods

We conducted a survey and interviews to learn more from students about their experiences taking courses with the new resubmission system.

3.3.1 Survey

All students at the University of Washington were invited to participate in anonymous end-of-term course evaluations, and professors had the ability to include their own questions. In two of the courses with resubmissions, in both sections of each course, we collected survey data about resubmissions by adding questions to a standard, web-based course evaluation form. The "Survey" column in Table 3.1 indicates which courses. The course evaluations were administered in the final weeks of instruction, with the assurance that instructors would not see responses until after grades were submitted.

We added one multiple choice question, answered on a five-level scale from "strongly agree" to "strongly disagree":

1. Feedback provided on graded assessments helped me understand how I could improve my work

and two open-ended questions:

2. How many weeks did you resubmit an assignment this quarter, and what were your primary reasons for resubmitting?
3. For assignments you chose NOT to resubmit, what were your primary reasons for not resubmitting?

These questions were designed to answer our research question about students' reasons for resubmitting.

Survey analysis

The third author coded responses to the open-ended questions. For the question about reasons for resubmitting, coding was done in two passes. In the first pass, each response was coded inductively with one or more primary codes, yielding the codes in Table 3.2A. In the second pass, responses were labeled based on their primary codes with zero or one of two secondary codes, listed in 3.2B. For the question about NOT resubmitting, inductive coding was done in one pass, yielding the codes in Table 3.3.

A. Primary Resubmission Code
To raise grade
To correct, improve, complete work
To improve style, correct comments
Ran out of time for first submission
To increase coding confidence
To learn
Guided by TA feedback

B. Secondary Resubmission Code
Only to raise grade
Only non-grade reasons

Table 3.2: Reasons for Resubmission: Codebook

3.3.2 Interview

We recruited interviewees from the pool of all students enrolled in the courses that used the resubmission system. The "Interview" column in Table 3.1 indicates the courses where we recruited students for interviews. We emailed students with an interview interest survey. Twenty-three students indicated willingness to participate in an interview. We invited each of the twenty-three students to schedule a video call interview time using a web-based appointment calendar. Ten students scheduled, and nine showed up to the appointment and completed the interview. Table 3.4 indicates which resubmission-based courses each participant had taken. All the students who we interviewed had taken CS1 and/or CS2 with resubmissions, and the interviews focused mainly on those courses.

All interviews were approximately sixty minutes in duration and were conducted over video call during the summer of 2021. We used a semi-structured critical incident protocol

Not Resubmiting Code
Grade maxed out
Satisfied with grade
Not applicable resubmitted all
Nothing to fix or improve
Satisfied with learning
Did not improve work
Insufficient time/motivation to resubmit work
Forgot to resubmit
Prioritizing another resubmission
Ran out of resubmissions
Consideration of TAs time
Guided by TA feedback

Table 3.3: Reasons for NOT Resubmitting: Codebook

to ask students about the resubmission process. The protocol focused on a piece of work that students had resubmitted as part of their coursework, and when students had trouble deciding which piece of work to bring, we prompted them to choose the work they were proud of. This encouragement was made in the hopes of providing an opportunity to discuss CS identity and rightful presence. The second author led the interviews. The first author took notes in a document that captured participant answers and researcher observations, asked an occasional follow up question, and led the interview for a few minutes during one time when the second author temporarily lost internet connectivity. As part of the interview process, we asked students to "Make a slide describing yourself, both inside and outside of the classroom. Feel free to include any images, drawings, words, whatever– and would you mind talking me through this process?"

After the interviews, students were sent a follow-up email that included a survey to collect demographic data and gift card preferences. Students were offered a $25 gift card to local businesses as compensation for their time. At the time of the interviews, the local minimum wage was $16.69 per hour.

After drafting the findings section of this paper, the authors engaged interviewees in a member check to validate that the draft accurately represented each student and elicit corrections in case of error. Eight out of the nine interviewees replied to the member check email: two made minor corrections, and six validated the manuscript with no corrections. We interpreted non-response as acceptance of the draft.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
CS1	✓		✓	✓		✓	✓	✓	✓
CS2 (2020 autumn)		✓			✓				
CS2 (2021 winter)	✓		✓	✓		✓	✓		✓
Data Programming 2	✓								
Data Structures and Algorithms		✓							

Table 3.4: Courses Taken with Resubmissions

Interview analysis

Interview analysis consisted of thematic coding. The first and second authors inductively coded the notes documents that they had recorded during each interview. Because of the motivations of the course instructors, they paid particular attention to evidence of CS identity and rightful presence while coding. Relying on the work of Hammer and Berland [35], which finds qualitative thematic analysis as interpretive claims not quantitative data, we do not report inter-rater reliability. Instead, we provide our process and codebook that helped us to arrive at our shared interpretation. After coding one interview, the researchers came together to compare and establish a preliminary code book. They engaged in the same process with subsequent interviews, coding separately then meeting to discuss and arrive at consensus for the codes on each of the nine interviews. The most relevant codes of the code book are reflected in our findings below.

3.3.3 Positionality

The first author is a PhD student preparing for a career teaching undergraduate CS, and was a TA for one of the courses in this study. Holder of a bachelor's degree in CS, she recognizes the CS education system as a gatekeeper to the individual, collective, social, political, and economic power that comes with programming skills. She is white and culturally Jewish.

The second author is a white woman who brings a critical lens to STEM education, a PhD student with 2 years of computing education research, and 11 years of math, engineering, and computer science secondary classroom experience.

The third author is an educational developer who has worked with both instructors featured in this paper and sees his role as promoting partnership between educators and students. He has a Ph.D. in CSE and 15 years of experience with mixed-methods research in engineering education. His past work has examined gender in CS but is new to the broader literatures relevant to equity in CS education. He identifies as Japanese American.

The fourth author was the instructor for two of the courses in this study. He is a teaching professor in a school of computer science and holds degrees in computer science and education.

The fifth author is an Asian male teaching professor in computer science, and the instructor for one of the courses in this study. His teaching philosophy grew out of a desire to ensure that all students could not only participate in the computing community, but also reauthor CS to realize their own values and purposes. This equity framing inspires his current research directions in critical, reflexive, justice-centered, and culturally-responsive teaching practices.

3.4 Findings

Our qualitative approach sought to examine the range of ways in which students related to the resubmission policy and other constructs of interest, such as CS identity.

3.4.1 Reasons for resubmission

Course evaluation response rates for the four sections varied between 39% and 48%. 573 students responded to the question about feedback, and 94% agreed or strongly agreed that feedback on assessments helped them understand how to improve their work.

A total of 418 students responded to the open-ended question about reasons for resubmitting. When analyzing this question, several reasons emerged, shown in Table 3.2A. Just under a third of students mentioned a higher grade as their sole reason for resubmitting. However, many gave multiple reasons, and over half of the students mentioned improving or completing their assignment among their reasons, as in these responses: "*I wanted to address the feedback on my assessments and make sure that I had a firm understanding of what the feedback was encouraging me to work on*," and "*I wasn't able to finish the assignments by the deadline. I ran into bugs and couldn't figure out how to fix them.*"

219 students responded to the question about resons for not resubmitting. The codes in Table 3.3 emerged when analyzing this question. Some students were unable to resubmit for reasons of maxed out grades, or there was nothing that needed to be fixed or improved. Some students did not resubmit because they made decisions to invest in other work, or there was insufficient time. Some students were considerate of TA time or feedback. Some students ran out opportunities to resubmit. Grade-based reasons were the most common reasons for not resubmitting.

3.4.2 Impacts of resubmission

Students looked at their feedback. Interviewees overwhelmingly demonstrated having read TA feedback on initial submissions in order to know what revisions to make for the resubmission. For example, S4 used TA feedback to identify areas overlooked and make

incremental changes between the first and second submissions. Two students reported learning gains from their feedback beyond revising the given assessment for resubmission. In specific, S7 used TA feedback to build an intuition about method breakdown and S1 transferred feedback to the following quarter, saying "*the feedback I was getting in [CS1] I definitely enacted in my [CS2] projects.*"

Resubmissions take the pressure off. Resubmission opportunities take the pressure off by enabling students to achieve high grades incrementally. For example, S3 observed getting perfect grades on all assessments, after resubmission. With resubmissions, there is less pressure to submit work that earns top grades on the first try. As S6 states, "*It's okay if I screw it up this time, at least I can go fix it. ... I felt a little bit, you know, safe because I could always resubmit it again.*" Furthermore, clear TA feedback on the initial submission can support confidence on the resubmission, as S1 describes,

> "I felt a lot better about my submission the second time around, because the first time I was kind of unsure like did I do everything right and then, once I got feedback, I was like okay I'm definitely heading in the right track, I have most of it down."

Focus on student learning. S4 enjoyed learning the pedagogical principles behind resubmissions, saying

> "[The instructor] took the time at the beginning, in the first lecture to talk about the structure and explain, like the process of resubmission and... philosophy of teaching the course of like you're not gonna nail it on your first try and it is important... that you have this space to get feedback and improve."

S4 perceived this as a focus on student learning, in contrast with the expectation, from talking to other students, that CS1 and CS2 would be weed-out courses.

> "I think the general energy from the course was definitely a lot lighter and I think part of that does have to do with the focus on student learning. ... By talking about pedagogy it shows like a sense of care... enabled more learning and more you know, actual engagement with the content rather than freaking out about everything. That was really nice."

But, as S4 acknowledges, this may not have been everyone's experience.

S7 appreciated resubmissions in the context of being a newcomer to CS, saying "*the resubmissions were really great especially it being my like first you know coding class.*"

Connection to professional practice. One student reported a connection between course structure and feeling more like a computer scientist. S9 said that the

> "greater focus on assessments, instead of focusing on grade is a great way to make me feel like I'm actually in a real world situation I'm trying to solve a problem instead of just trying to crunch numbers."

Complaints about the resubmission system. Some students took issue with parts of the resubmission system. Some students felt that the grading system was not well defined enough to figure out their current standing. S2 observed that ESNU grading was unfamiliar and confusing at first, and reacted by aiming to get an E in everything to avoid having to do any calculations to understand current standing. S7 similarly reported uncertainty about the final grade. Understanding the bucket system was not sufficient for S7 to calculate a final grade because the bucket system did not define any way to calculate grades between 3.5 and 4.0. S5, who felt underchallenged in CS2 and was motivated by grades, perceived resubmission opportunities and feedback as demotivating.

3.4.3 Limitations of our resubmission system

Some students described systemic issues that are present in many classrooms. As with most incremental changes to course policy, resubmission grading did not solve these issues.

Some students described a tension between learning and their performance (i.e. grades) as a student. S4 reported that "*I used the resubmission process as a way to just get more points, whereas I could have had it probably be more meaningful in my learning.*" S6 felt that cumulative assignments were more helpful for learning, but observed the stress of finals made it hard to want to do cumulative things.

One student lamented that simple mistakes that didn't reflect a lack of mastery could significantly impact the final course grade. S7 attributes earning a final course grade of 3.9 instead of 4.0 to having one extraneous space in one resubmission, while the rest of that file and other work was indented according to the code quality guide. S7 expresses frustration over this by saying "*I know you guys know I can do this.*"

In addition to mastering computer science topics, learning the system seemed to be important for earning top grades. After having taken AP CS, S4 chose to take CS1 to, in S4's words, "*get initiated into the course structure.*" S1 was highly motivated by grades, and made a spreadsheet to track them to better understand what was needed to earn the top final grade.

S8, motivated by grades, saw the reflection attached to the resubmission process as a hurdle in the way of improving grades.

Forming CS Identity. Other than the one student who felt resubmissions simulated a real life situation and connected that to feeling like a computer scientist, we did not find much of a connection between resubmissions and CS identity formation. We do not have sufficient evidence to claim that resubmissions or course policies alone are enough to allow for CS identity to take root and flourish. Instead, students reported other factors – collaboration, relationships, open ended projects, and opportunities to learn about applications of CS – as making them feel more like a computer scientist, in response to our interview question on that topic.

For example, S6 really appreciated the "TA's choice section" in the last week of classes, where TAs presented topics of their own interest. S6 was considering a career as a software developer, and the TA's choice section helped S6 to form a concrete vision of what that professional practice might look like. S6 predicted feeling more like a computer scientist if given the freedom to make design decisions while coding. Another student, S7, similarly saw potential for feeling more like a computer scientist in connection with creative choice in programming and opportunities to learn about CS ethics and applications.

S8's path toward CS identity was more related to study skills. S8 failed CS1 at first, but retook it the next quarter, and advanced to CS2. S8 developed study skills along the way, including avoiding distractions while studying and asking more questions. Near the end of CS2, S8 felt confident and noticed personal growth, saying "*I felt like I was on fire... if I could redo [CS1], ... I could finish all the assignments in a very tiny fraction of the time.*"

S2 described working on an open ended project with peers for a web development class: "*I sent it to my friends, was like, 'Hey look at this website that I made!'*" S2 noticed feeling more like a computer scientist after that class. In wishes for future students, S2 included fostering community and opportunities to build relationships. Likewise, S1 predicts future collaboration opportunities will be valuable towards feeling like a computer scientist.

Fear of academic misconduct inhibited collaboration. The connection between collaboration and CS identity brings our attention to the formation of collaborative relationships between students. One finding that shocked us was how some students actively avoided collaborating with peers for fear of violating the academic misconduct policy. When asked about collaboration with peers, S2 answered

> "I was pretty stressed and I think a lot of my friends were really stressed that like about the whole collaboration and academic honesty stuff... So if I had questions I'd go to office hours. But for [another class] it was all collborative and I got to work with two informatics friends and we became really good friends."

We asked how S2 would change the course, the response: "*Help students foster connections*

with one another and feel comfortable coding together." S3 reported not collaborating on assignments because

> "the rule, was try to avoid collaboration as much as possible. So I decided not, like I would just not collaborate at all just to avoid any kind of academic misconduct shenanigans. So yeah, I just tried to avoid those and do anything by my own self."

It seemed that students were limiting their ability to learn through collaboration to avoid an academic misconduct penalty.

3.5 Discussion

The results of this study answered RQ1 on reasons for resubmission by finding both grade related reasons and other reasons, including learning and improvement related reasons.

We answered RQ2 on the resubmission experience by finding that students looked at their feedback and could achieve high grades incrementally, taking the pressure off the need to earn the top score on the first try, which are both experiences of competence. This result connects to my thesis statement by connecting the course policy on resubmissions to satisfaction of the need for competence. Inasmuch as satisfying students' need for competence supports their belonging (a claim for which I present evidence in chapter 4), resubmission policies can support belonging in part. These positive outcomes of the resubmission experience are also compelling evidence in support of instructors implementing resubmission policies.

We answered RQ3 about resubmissions and belonging by finding that one student connected resubmission opportunities to professional practice, which is insufficient evidence to conclude more generally that resubmissions make space for students to belong. I will discuss this more in depth, along with other limitations of the resubmissions study, in chapter 5.

For other students besides that one, belonging came from outside the grading system. They found belonging in experiences of autonomy, such as open-ended creative assignments and choosing which special topics to learn about, and in experiences of relatedness, such as opportunities to collaborate. These results support my thesis statement by providing evidence that satisfaction of psychological needs for autonomy and relatedness can contribute to belonging. However, we found that the academic misconduct policy acted as a damper on belonging by discouraging students from collaborations where they could have made personal connections with peers.

Chapter 4

"A FIELD WHERE YOU WILL BE ACCEPTED": BELONGING IN STUDENT AND TA INTERACTIONS IN POST-SECONDARY CS EDUCATION

In this chapter, I describe an interview study where I investigated student and TA conceptions and narratives of belonging in a post-secondary computer science environment. I conducted the work in this chpater in collaboration with Jean Salac and Amy Ko.[1][2][3]

We were motivated by the fact that in the CS program at the Paul G. Allen School of Computer Science and Engineering at the University of Washington, Teaching Assistants (TAs) have the majority of student contact hours, making student-TA interactions, such as those during office hours, important in shaping student belonging. Therefore, we sought to understand student and TA conceptions of belonging, their narratives about their journeys of belonging in CS, and how TAs influence student sense of belonging through office hour interactions. We studied students and TAs in 4 Allen School CS courses, including introductory, intermediate, and advanced; core and elective, interviewing them about their belonging in post-secondary CS. We conducted semi-structured 1:1 interviews with 14 participants, consisting of 7 pairs of students and TAs who interacted in office hours. Student and TA conceptions and narratives of belonging aligned with the three basic needs for wellness as described in Self-Determination Theory: relatedness, competence, and autonomy. Some also surfaced needs for safety and access as key components of belonging. TAs and students reported that TAs supported student needs for competence, relatedness, and autonomy by fostering understanding of material, treating them with empathy, helping them see peers positively, and helping them to own their own success.

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[1] I use the term "we" in this chapter to acknowledge the shared contribution of all authors.

[2] I wish to thank Jayne Everson, Dan Grossman, and the students, TAs, and instructors involved in the study. This material is based upon work supported by the National Science Foundation under Grant No. 1539179, 1703304, 1836813, 2031265, 2100296, 2122950, 2127309, 2137834, 2137312, a grant from the Center for Inclusive Computing at Northeastern University, and unrestricted gifts from Microsoft, Adobe, and Google.

[3] This chapter is based on an article published in the Proceedings of the 2023 ACM Conference on International Computing Education Research (ICER '23)[60].

4.1 Introduction

Belonging is a basic psychological need necessary for human wellbeing [9, 49]. In post-secondary CS, many factors shape belonging [68], including physical environment, curriculum, academic performance, self-efficacy, peers, and CS culture [17, 26, 79, 65, 80, 45]. Emerging work suggests that TAs can play an important role in community and inclusivity [4, 75].

While prior work makes clear *that* TAs matter, it has not yet examined *how* TA identity and behavior shape belonging. For example, it may be that shared racial or gender identity with TAs is central. Or, it may be that TAs' interpersonal behavior is the key mechanism for shaping belonging. Or, it could be that in CS, TAs' most important contribution is simply to be more available for programming help than faculty. Or it could be that all of these interact to promote or erode a sense of belonging. Because these possibilities have not been explored, it is difficult to inform how TAs should be trained and supported to promote belonging.

To address this gap, in this paper we focus on the specific context of office hours. These are where students and TAs often interact most directly, so they offer a granular lens on how students experience TAs and their behavior, but also how TAs intend that behavior. We ask three questions about these contexts:

- RQ1: How do both students and TAs conceptualize belonging, both through direct descriptions of what belonging is, and through narratives about their journeys of belonging in CS?

- RQ2: What do TAs do to try to promote the student's sense of belonging in CS office hours?

- RQ3: What do students perceive TAs doing during office hours, intentionally or unintentionally, that shapes their sense of belonging in CS spaces?

To answer these questions, we observed office hours and then conducted semi-structured 1:1 interviews with 7 pairs of TAs and students who had recently interacted in office hours. In interviews, we asked them to describe their narratives of belonging in CS, their concept of belonging, and to explain any connections between office hour experiences and belonging.

4.2 Methods

In this study approved by our university's institutional review board, we conducted semi-structured 1:1 interviews with 14 participants, consisting of 7 pairs of TAs and students who had interacted with each other in office hours, with interviews occurring as soon as possible after their office hour interaction.

4.2.1 Context

The study took place at a the Paul G. Allen School of Computer Science and Engineering (Allen School), at the University of Washington (UW), a large, public, North American university. We recruited participants from four undergraduate CS courses, displayed in table 4.1. During the summer term of the study, most courses in the department enrolled fewer students than during the academic year, and it was easier for non-majors to enroll in CS major courses, but course content was the same. Campus-wide data suggested that summer courses enrolled fewer international students, due to higher tuition. Despite smaller enrollment, courses were structured similarly to academic year offerings of the same courses enrolling up to 250 students. Each course in the study had two kinds of instructors: the lead instructor and a team of TAs. As during academic year offerings, the lead instructor delivered lectures 2-3 times per week and coordinated the TA team, while typical TA duties included grading, office hours to help students with classwork, teaching weekly "recitation" sections reviewing content in smaller groups, and weekly staff meetings for the instructor and TAs to discuss course logistics. It was common practice in the department to offer summer lead instructor roles to students. Of participating courses, one instructor was a doctoral student, one was a Master's student, and two had graduated from the program with a Bachelor's degree just before teaching.

The CS department encouraged TAs to enroll in a paid TA training seminar during their first term as a TA, meeting one hour per week. The primary seminar audience was new undergraduate TAs, and topics included professionalism, ethics, teaching scenarios, teaching and learning, grading, feedback, academic integrity, active learning, and restructuring a recitation section [1]. Of TAs in the study, two had attended all sessions, two had attended fewer than half, two did not attend, and one did not report.

Course	Undergraduate level[4]	TAs	Students	Study participants
CS2 for data science	Introductory	9	58	S5, T5, S7, T7
Probability and statistics *	Intermediate	6	46	S6, T6
Computer organization *	Intermediate	4	50	S3, T3, S4, T4
Machine learning for non-majors	Advanced	5	42	S2, T2, S9, T9

Table 4.1: Courses participating in the study, levels as listed in the course catalog, number of TAs employed, number of students enrolled at the conclusion of the term, and IDs of study participants in that course. Asterisks (*) denote courses for CS majors, where students not admitted to the major needed special permission to enroll.

[4]Introductory courses were academically accessible to first year students, intermediate courses were designed to be taken towards the middle of a four-year degree, and advanced courses towards the end.

4.2.2 Recruiting instructors and TAs

First we recruited instructors, requesting permission to recruit TAs and students. The first author recruited instructors teaching undergraduate CS courses during the summer 2022 academic term, who the first author perceived would be open to the study, based on prior indicators of interest in inclusion. For each course, the first author visited the staff meeting to describe the research to TAs and recruit TAs. The instructor stepped out of the staff meeting so as not to know which TAs volunteered for the researcher to visit their office hours. Then the first author visited class to describe the study and ask students to participate if they showed up to a participating office hour. Students and TAs were informed that their participation would not impact employment or class standing and that the researchers would not apprise the instructor of participant identities.

Recruitment messages expressed the researcher's interest in talking to participants who identified with minoritized groups or had experienced fluctuations in belonging. TA recruitment messages were designed to appeal based on interest in inclusivity and belonging. This feature means the study data primarily reflect TAs working to create positive climates of belonging. Another feature of the recruitment design is paired recruitment of TAs and students, producing data exposing multiple perspectives of the same interactions. As a side effect, each participant knew their paired counterpart was in the study, and students did not express much negative feedback about their paired TA.

4.2.3 Recruiting and selection

The first author observed each TA's office hours once or twice during the term, primarily for recruiting students to the study. The researcher and TA met for 10-15 minutes before a mutually agreed upon office hour. The researcher coordinated with the TA to incorporate the study procedure into the TA's office hour, following the TA's preferences and preferred office hour practices. Office hour observations were spread over 2 weeks toward the middle of the term.

Office hours took place virtually by video call or in academic building breakout areas. Breakout areas were lounge-like study spaces with whiteboards, tables, chairs, and couches, accommodating about 10-20 people. Breakouts were commonly reserved by TAs for office hours, but students from other courses often also used the space during office hours. In virtual office hours, the TA created a private virtual room to help each student one-on-one while other students waited together in a non-private virtual room.

During office hour observations, the TA introduced the researcher to each student at the start of the student's turn, asking permission for the researcher to observe. After obtaining permission, the researcher assumed a non-invasive presence to minimize observation bias while

listening to the interaction and taking notes. On video call this meant turning off camera and microphone. In breakout rooms, this meant sitting within earshot. either across the table or a few seats away, keeping a distance similar to students who were waiting their turn. The researcher observed by listening rather than watching most of the time, taking notes on a laptop. Students and TAs hardly looked at, talked to, or otherwise acknowledged the researcher, and did not appear to be distracted by them during the office hour interactions.

At the end of the student's turn, the researcher offered to answer questions about the study, and asked the student to fill out a survey about their identity and office hour interaction (table 4.2a). Meanwhile, the TA filled out a survey about the interaction, (table 4.2b). At the end of the office hour, the researcher offered to answer questions from the TA and the TA filled out a survey about their identity and experience level as a TA (table 4.2c).

Responses were captured as free text, except where indicated. Questions were optional except where indicated. Instructions on each survey included an estimate of the time required and brief description of the purpose. Surveys contained a link to study information, including researcher contact information and confidentiality statement. Survey data were used as selection criteria for interview invitations, and to help participants remember details of the office hour while interviewing, but were not used directly in the analysis.

Student Office Hour Survey (5 minutes)
[Page 1] Belonging and CS TAs research study • Name (required) • Based on this survey, you might be invited to a 30-50 minute interview to share more details about this office hour interaction and your sense of belonging in the course. Your privacy will be protected, and you will be paid for your time interviewing. If invited, do you think you might be interested in interviewing? (required) [Multiple choice] — Yes / most likely [leads to page 2] — Maybe / not sure [leads to page 2] — Definitely not [leads to end of survey]
[Page 2] Your Office Hour Conversation • TA Name • Write a couple sentences briefly summarizing the interaction you had with your TA just now. (required) • Briefly describe how this conversation impacted your sense of belonging in the course. (required)
[Page 3] Your Identity • **[Identity Questions]**

(a) Student survey.

TA Identity and Experience Level Survey (2 minutes)
• How would you describe your experience level as a TA? (required) Include teaching-related experience from this course and other courses, both at UW and outside UW • **[Identity Questions]**

(b) TA identity survey.

TA Office Hour Survey (2 minutes)
• Student name if you know it • Write a couple sentences briefly summarizing the interaction you had just now with the student named above. (required) • Briefly name things you did to try to help the student feel a sense of belonging. (required)

(c) TA office hour survey.

Table 4.2: Office Hour Surveys. Surveys 4.2a and 4.2b also included identity questions to self-describe gender, ethnic identity, languages spoken at home, and disabilities.

4.2.4 Interviews

I communicated with prospective interviewees and conducted interviews over a 2 week period near the middle of the term.

We selected who to invite for interviews based on survey data. We prioritized inviting:

- Students with longer, more detailed responses to the question about how the office hour interaction influenced belonging.
- Participants identifying differently from those already scheduled to interview, to have a diverse set of genders, ethnic identities, and abilities represented in the study.
- Students taking different courses than students already scheduled to interview.
- TAs with different self-reported levels of TA experience than TAs already scheduled to interview.

We sent interview invitations to students the same day as the observed office hour or the next day whenever possible. Multiple students filled out the survey for most of the TA office hours, but we only interviewed up to 1 student for each TA. First, we invited our top choice interviewee. If they declined, we invited the next choice. To reduce delays from declined interviews, we prioritized inviting the most interested participants. After a student scheduled their interview, we invited the paired TA. We tried to schedule interviews as soon as possible after observed office hours as scheduling constraints allowed. 10 participants interviewed 1-2 days after, and 4 participants interviewed 3-5 days after. To mitigate effects of forgetting interaction details, the interviewer showed participants their survey responses. We offered interviewees a preference between in-person and video call, with in-person interviews held in a private user study room.

We conducted semi-structured interviews in English, and recorded audio with participant consent. Given the format, there were differences in question phrasing, building on context established with each interviewee, and different probing questions to satisfy the researcher's curiosity about all topics in the interview guide. Interviews ranged from 30-80 minutes in duration, with most interviews lasting about 1 hour. Table 4.3 summarizes questions.

In interviews, we did not provide a definition of belonging because we did not want to bias participants and restrict them to only telling narratives that matched the researchers' definition of belonging. Instead, we asked participants to define belonging about halfway through the interview, after talking about their journey of belonging in CS, so they had context to structure their definition.

After producing each major draft of this paper, I engaged interviewees in a member check to validate that the manuscript accurately represented them and elicit corrections. All participants validated both drafts the manuscript, including 4 who made minor corrections to the first draft, and 2 to the second draft.

TAs were compensated by gift card, or as part of their TA paycheck, depending on instructor and TA preferences. Hourly TAs received their standard TA pay rate, $17.79-$21.79 per hour. Salaried TAs were paid at the top of that range. Student interviewees were paid $17.79 per hour by gift card.

Template
• Why did you choose to participate in this research study? • Describe your journey of belonging in this course. • How do your identities tie in with your journey of belonging in CS spaces? • In what we just talked about, what is your definition of belonging? • Tell me your story of how the observed office hour went for you. [TA- or student-specific questions] • Do you have any questions for me?

(a) Interview guide template.

Student
• What did the TA say or do during this interaction that increased/decreased your sense of belonging in this course? • If a new TA asked you for advice from your perspective as a student on what to do/not to do to help students feel a sense of belonging, what would you tell them?

(b) Student-specific questions.

TA
• What did you say or do during this interaction to try to help the student feel a sense of belonging? • What do you do in general as a TA to help students feel a sense of belonging? • If a new TA asked you for advice on what to do/not to do to help students feel a sense of belonging, what would you tell them? • What value is there in students developing a sense of belonging in CS spaces? • Do you see it as part of your job to help students develop a sense of belonging?

(c) TA-specific questions.

Table 4.3: Interview questions. The interview guide template (4.3a) was used for all interviews, with student-specific (4.3b) or TA-specific (4.3c) questions, depending on interviewee.

4.2.5 Participants

There were 14 interview participants, consisting of seven pairs of students and TAs who interacted during the observed office hours. Participant names have been replaced with participant IDs for anonymity. Participant pronouns have been replaced with participant IDs or the generic pronoun "they" since we did not ask for pronouns. Participants who shared an office hour interaction share the same number, while letter indicates role in office hour interactions: 'S' for student and 'T' for TA. One TA was a PhD student and the other participants were undergraduates, including five CS majors. Five participants reported CS experience before college. Table 4.4 displays participants' self-described gender and self-described ethnicity and table 4.1 shows each participant's course.

ID	**Gender**	**Ethnicity**
S2	Female	Korean
T2	Cisgender Male	Taiwanese-American
S3	male	vietnamese
T3	Male	South Asian
S4	Cis Male	Latino
T4	trans man	white
S5	Female	I think Asian or a mix of American and Asian
T5	Cisgender Female	Korean American
S6	Male	Caucasian
T6	Female	mixed race Chinese and Caucasian
S7	Female	Asian
T7	Male	Asian
S9	Genderfluid	East Asian
T9	male	white/caucasian/german

Table 4.4: Participants' self-described gender and self-described ethnicity. Capitalization and punctuation are as participants wrote them.

4.2.6 Analysis

The second author transcribed interviews using otter.ai, an automated web transcription tool. To establish soundness in our analysis, two researchers contributed to coding. Both developed a code book using not only inductive themes from interview content, but also deductive themes derived from research [19, 70]. The first and second author coded transcripts, using agreement through consensus rather than inter-rater reliability to ensure consistency [36]. Both coded one transcript together. Then the first author coded a second transcript while

relying on the second author to resolve many uncertainties. By this point the first and second authors had arrived at a shared understanding of codes. Then the first author coded the rest independently, consulting the second author on occasional uncertainties. The first author then applied thematic analysis to coded transcripts.

After receiving feedback and reading more background literature, the authors re-coded transcripts with additional themes informed by literature. The first and second author jointly selected new themes. The first author re-coded transcripts, consulting the second author to resolve uncertainties. The first author then applied thematic analysis to revise and add to the first analysis draft.

Aggregated across both coding rounds, autonomy codes were the most uncertain because of ambiguities around how the definition of autonomy from SDT manifested in the data. Competence and relatedness codes had some uncertainty because it was sometimes unclear if a quote was sufficient to justify coding it under those themes.

4.2.7 Positionality

The first author is a culturally Jewish white woman and approached this research as (1) a former undergraduate and TA at a small liberal arts college CS department, where she obtained a Bachelor's degree in CS and (2) a PhD student and current and TA at the university CS department where the study took place. Her motivation to conduct this research arose in part from seeing room for improvement in the undergraduate TA program at the university. She played a lead role in the research, designing and executing the research methods with support from the other authors.

The second author approached this research as (1) a former undergraduate in a large, public, research-intensive university in the US with an established TA training program (similar to this study's context) and (2) a former TA in her undergraduate and graduate studies. As a member of several marginalized groups in computing, she experienced both positive and negative interactions in both positions. She played a supporting role in the research, collaborating with the first author on data analysis and interpretation.

The third author is a computing education researcher and professor with interests in diversity, equity, and inclusion in computer science learning contexts. She was positioned in this work as an advisor, providing guidance on research and methods, but not directly engaged in data collection or analysis. She approached this work with some curiosity about student and TA perspectives about their mutual interactions, but not with a particular a priori hypothesis about what they might say. She approached the research question from a place of ignorance, having never attended a CS office hour when she was an undergraduate in CS.

4.3 Results

In interviews, students and TAs described their concepts of belonging in CS. Their belonging needs aligned with fundamental needs for safety and resources and with the three basic needs of SDT: relatedness, competence, and autonomy (RQ1). They also described TA actions addressing those needs (RQ2, RQ3).

4.3.1 Concepts of belonging

Participants described a diversity of conceptions of belonging (RQ1), most mirroring prior work; interactions between students and TAs revealed numerous aspects of communication, pedagogy, and identity that shaped belonging. Note: quotations below represent parts of participants' concepts matching each theme, not necessarily each participant's entire concept of belonging.

Competence

As members of an academic community centered around CS knowledge, students' competence greatly influenced their belonging.

The theme of competence arose frequently, sometimes in combination with safety. In T9's concept of belonging, competence came up as its own component: "*to feel like you can be successful.*" Others described safety as interconnected with competence. For instance, S2 said that belonging was feeling "*safe enough to ask questions and have that maximum potential to learn something,*" and T2 described it as "*not feeling like you're going to be alienated or made fun of or put down if you reach out for help.*" S6 articulated how lack of safety around group competence could inhibit belonging, saying:

> "not belonging... is where the people are very guarded, closed down... someone asks a question, no one raises their hand because no one wants to take a risk of being seen as wrong or judged."

Participants described how their own prior knowledge could contribute to belonging (S6, T2), while lack of prior knowledge relative to peers could detract from belonging (S3, S4, S6, S9, T2, T4, T9). Some noted how acknowledging everyone's differing skill levels and that experienced peers also struggled could mitigate this (S6), as could receiving encouragement from the instructor (S4).

Many students described learning as another facet of their competence. For example, participants reported feeling greater belonging as they noticed their progression through the course material (S3, S4, S9). They also indicated that performance, measured by grades (S3,

S4, T3, T4, T9), and self-efficacy contributed to their belonging (S4, S5, T2, T4, T9). For S4, a first generation[5] university student, self efficacy helped overcome doubts related to identity.

> "The fact that I got a really good grade for [CS1] let me know that I wanted to study computer science. It also reinforced the fact that I felt confident in my ability to do it in the first place. Regardless of the notion that not many Latinx individuals are in tech."

T9 described a connection between competence and relating to others through teaching and peer review, which supported belonging:

> "They review your work, they accept it, they publish it. ... Teaching has helped with that as well. Because over time, I mean, you're literally like the person communicating to a new person, what this field is about."

Students who did not start their university CS education in a 4-year institution noted the importance of certain prerequisites for competence, and how lacking those harmed belonging. T9, who started CS as a graduate student with an undergraduate degree in humanities, used the term "hidden curriculum" to describe this phenomenon, saying,

> "IDEs and editors, like vim or Emacs. Often these things are not taught, or they're taught in a cursory way. ... Those were huge stumbling blocks."

Similarly, S6, who transferred from a 2-year community college, said:

> "There should be a tutoring center for the [intermediate] classes. ... If you see no path between here and there, then that can be crushing and demoralizing in all sorts of ways."

S6 envisioned that the tutoring center, unlike office hours, would focus on study skills.

Relatedness

Among the predominant components of the need for relatedness were needs for safety, community, and positive self image relative to peers.

Participants most frequently conceptualized belonging in terms of relatedness – ways they socially connected to peers and instructors. T6 conceptualized belonging as contribution with "*you have a place... you're contributing to the energy that the group has.*" Some

[5] *first generation* refers to a university student whose parents did not go to university

conceptualized belonging as others' reception, saying "*if you don't come to that class, you feel like people are missing out on you*" (S9), that belonging is a feeling that CS is "*a field you're where you will be accepted*" (T4), and that "*you are valued or at least tolerated or permitted*" (T9). S4, who had reported being the only Latinx person in the room, described the opposite of belonging as "*if you feel like everybody knows each other, whereas you're the only one, that can sometimes be isolating.*" S6 shared a collective concept of belonging, saying "*among a group of people things are working smoothly and as expected.*" S7 characterized belonging in terms of course staff, indicating that belonging was high when the "*instructor and TAs... actually care about their students.*" In some concepts of belonging, relatedness was interconnected with competence. S3 described belonging as feeling "*confident enough to tell [peers] my implementations,*" and S6 described it as being "*unified in your ignorance.*"

Students reported fear and discomfort associated with office hours and classrooms, revealing a need for TAs to actively make a safe space. For example, participants observed that when TAs put students down with condescending, dismissive, or disparaging remarks, it harmed belonging (S3, S4, S6, S9, T2, T3, T5, T6, T7). T4 explained that telling students they should know something signaled both non-acceptance and a belief that they could not succeed, connecting to both relatedness and competence. S2 reported a profoundly uncomfortable experience with an organic chemistry TA:

> "I was just sitting there asking very basic questions and he would literally just stare at me. For so long.... I felt like I was being picked on. ... He would kind of say things like like 'we literally just went over it.' ... And it just made me feel so uncomfortable."

They contrasted it with feeling much safer with a more responsive TA. S5 described feeling nervous and paranoid about going to CS office hours, concerned that their question would be too small, uncertain whether they could articulate the question, and "*very uncomfortable about taking my TA's time.*" S3, a first generation student new to CS in university said, "*Being from my background, not knowing much computing ... a lot of students are scared of their first programming class*" S3 described taking a first intermediate CS class, where classroom social dynamics alleviated fear of incompetence they had felt in CS1 and CS2:

> "[The instructor] made sure that the classroom was like a safe environment. And he encouraged like talking to other people. ... The TAs are just way more approachable. ... I wouldn't feel scared about like, Okay, do I know this content before I even he even jumps into it."

T2 equated belonging with not being judged, saying:

> "Your TAs or professors who for sure know more than you are going to help you, and not judge you."

S6 described how being older than peers emboldened them to take a risk in a classroom situation where members feared judgment:

> "No one raises their hand, because no one wants to take a risk of being seen as wrong, or judged. ... Since I'm sort of an older outlier anyway, I will usually jump in and just take one for the collective team. Ask the dumb question."

Participants indicated that knowing people in their community could contribute to their sense of belonging. Students shared that their networks grew as they spent time at university (S3, T3, T7), perhaps starting with people they had known before college (S3, T3). T3, who is from Malaysia and only knew Malaysian students at first, started out knowing few people. Students described how meeting more people promoted a sense of community and increased belonging in CS (T3, T4). They noted this could be true even if the people were outside CS spaces. For example T2 described the impact of taking CS courses with statistics cohort peers:

> "I think especially like being with like a stat cohort as well, even though that's an external factor to CS, I felt that that still helps me feel like a sense of belonging."

Apart from knowing and interacting with real people, participants described how they could form negative perceptions of themselves relative to others, based on real or imagined characteristics, and how these comparisons could detract from belonging by making them feel isolated. S4, a first generation student new to CS in university, who was not a CS major but was taking a CS majors course as a senior[6], shared feeling uncertainty when comparing to CS majors, saying

> "At the beginning [of this term], I wasn't very sure if I would continue it because I felt like a lot of CS majors already kind of knew what was going on, even if they didn't."

S3, also a first generation student new to CS in university, described feeling intimidated in a CS2 class during their first year, by peers demonstrating prior knowledge, saying

> "There's so many people in this class... that pretty much know everything. And they're just feeding the teachers answers. And I'm just stuck, just trying to like understand what the teacher or the student was trying to say 10 minutes ago."

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[6]A *senior* is a student in their final year of a four year degree.

Making negative comparisons to peers was not a pattern reserved for beginners or students new to CS in university. For example, T4, a final-year undergraduate CS major who had taken CS courses in middle school and high school (ages 12-18), described presently regretting a lack of internship experiences, saying:

> "I've never done a summer internship. And that feels like it's expected here. You know, especially like you overhear people in the hallways talking about like, Oh, I'm going to Facebook. I'm going to Microsoft."

S3 expressed the difficulty of stopping mental comparisons, connecting this negative self talk with lack of belonging. In S3's words,

> "Once I have this feeling of just not comparing myself with other students, it's very hard to not do that right now to early stage. ... Then I know at this moment, I'm in– I belong in computing."

Autonomy

The ability to engage with CS on their own terms (or not), and choices that they made about how to interpret CS environments influenced participants' belonging.

Participants conceptualized belonging in terms of autonomy, in conjunction with other themes. S9 articulated a concept combining autonomy with competence, saying, "*you have to make yourself feel belong by keeping up with the class.*" T5 described how relatedness depends on autonomy, saying,

> "One, it's recognition of a community. And then number two, feeling as though you can be part of that community... and you have the choice to do that."

Genuine interest supported belonging in CS (S5, S9, T2) and motivation to study CS (S2, S3, T5, T7), whereas lack of interest could be a deterrent (T2, T6). Two participants reported contrasting experiences with Girls Who Code, free extracurricular CS programs for children in grades 3-12 (ages 9-18), affiliated with an international nonprofit dedicated to closing the gender gap in computing [29]. T6 ended up hating CS because they found it too feminized and too easy in a Girls Who Code setting, whereas S5's Girls Who Code experience made them empowered to study CS against family pressure, breaking gender-related boundaries of their parents. For S5, gaining competence in CS activated genuine interest and made them feel a sense of belonging. According to S5,

> "When I went into it, and I started learning more, I got more engaged. And then I started having a sense of belonging, because I was like, Oh, I'm interested in this, I want to do more of this."

T6 described escaping familial academic pressure to find a niche in CS. T6 described how they were interested in art, but their parents told them "*if I did any form of art, they wouldn't pay for my college. I had to do STEM*[7]." Presently, T6 did not feel a sense of belonging in CS as a discipline, but did feel belonging among a small community of artistic CS friends.

Some students described agency in their own belonging. S2, a neuroscience student, joined an interdisciplinary club combining neuroscience and machine learning (ML) as the neuroscience expert. They were the only woman, but described choosing a positive outlook to feel greater sense of belonging in the club. They saw themself proudly as among few neuroscience people who knew CS, and did not identify as a CS person, saying because they could "*barely code*." Motivated by interest in the club's course of study, they enrolled in an ML course where they chose to accentuate the positive to increase their belonging in that class. According to S2,

> "I could perceive things very differently if I focus on the fact that I am the only female in the classroom. ... If I didn't have a positive outlook, then I probably would have just been very closed off I would have not asked questions, and I would have just felt like everyone was judging me because I was different... but I just choose not to let myself go through that path."

Likewise, S5 explained that choosing to engage with a group was an important component of belonging. Similarly, S9 described agency in their belonging. For example, they took the difficult action of choosing to confront a peer for saying something insensitive, and improved relationship with the peer. They also articulated that it was a student's own responsibility to keep up with class material in order to belong.

Basic needs

Another component was basic needs. T3 raised safety as a component of belonging, saying belonging is when "*you feel comfortable where you are.*" Lack of resources could impede belonging, for example "*you don't have a good computer, and you probably have to write everything down*" (S4). We present examples of the need for safety in conjunction with competence in section 4.3.1. As an example of need for resources, S4 reported that learning about opportunities in CS was important towards belonging in CS. S4 described themself as low-income and Latinx, and explained that their parents, immigrants from Mexico, strongly encouraged and supported their decision to go to college, but had only a fifth grade education. S4 described learning about college and engineering in middle school and high school (ages 12-18) programs, saying,

[7]Science, Technology, Engineering, and Mathematics

> "That's how I knew that I wanted to do mechanical engineering and eventually got into the world of CS. Participating in these programs provides access to people who can't afford it and don't even know these places exist in the first place."

4.3.2 TA actions

Students and TAs articulated TA actions addressing the needs for safety, competence, relatedness, and autonomy described above, in terms of both specific TA actions in the office hour interaction that I had observed, and other office hour interactions, real and hypothetical. This section presents student and TA descriptions of office hour interactions, TA strategies and their rationale, and participant ideas of hypothetical TA actions relating to each theme. Note: TA actions addressing safety were also associated with relatedness or competence, and are described in sections 4.3.2 and 4.3.2 below.

Competence

Participants described how TAs supported student competence by fostering understanding of the material, a central component of the TA's office hour role.

Giving the student sufficient time was essential to support student understanding. Not only did participants share that it took time for a student to comprehend material (S3, T5, T7, S9), but also that a TA's patience showed care and made students feel valued (S5, S9).

According to participants, TAs worked to learn student context with the specific problem they were working on, which supported student competence and also respected student autonomy by helping students learn on their own terms (S3, S6, T3, T7). T6 described the strategy of asking students to explain their reasoning, which also supported student autonomy by engaging on the student's own terms. TAs described varying levels of prior knowledge that a student might have, and how TA assumptions about student knowledge could impact belonging (T2, T4, T7). For example, in an intermediate CS majors course, T4 described the strategy of "*not assuming prior knowledge,*" because "*if you assume that they know it, and they don't, it can feel embarrassing.*" In contrast, T2, in an advanced non-majors course with few prerequisites, described a strategy to "*assume a base level of knowledge and then you tailor it back,*" to avoid being condescending about basic knowledge that students do know.

Participants indicated that it was important for TAs to explain concepts to support student understanding rather than giving away answers. Some participants reported having TAs give away answers or partial answers was tempting (T2), easy (T9), or wished for (S9). However, participants underscored the importance for students to understand concepts or process underlying the answer (S2, T3, T9) and to have an active part in figuring it out

(T2, T6, T7), and some connected understanding to belonging (T3, S9). A reflection by S9 connects this to the autonomy theme of owning one's growth: "*If they just give you the answer, you will never learn. ... It's all about, like, making your growth yours.*"

TAs had different perspectives on why not to give away answers. T7, who had been a TA for one year in high school (ages 14-18), was a 2nd term TA at university, and had attended about half the CS department TA training. Their reasoning was based on student autonomy in learning:

> "If I guide them through everything and saying, let them to find out their own solution and mistake... they are making tons of contribution to their own work."

T2 was a 3rd term university TA and did not participate in TA training. Their reasoning was based on performance in a competitive environment:

> "it's kind of unfair if... this one student gets confirmation that this yes, is completely correct and the other 99 students or whatever in the class don't."

Though T2's own reasoning was based on performance, they also reported internalizing a fellow staff member's autonomy-based reasoning similar to T7's perspective.

In support of student understanding, some TAs described the importance of encouraging students to look things up (T4, T7, T9) However, students asserted that TAs should be better than online references (S9) and that referring to reference materials could be seen as a challenge to the student's preparedness or as reluctance to directly help the student understand (S4).

For S7, speaking to the TA in their shared first language was key to understanding. "*T7 can speak Chinese. So our conversation is more efficient. ... I can like describe my question more clearly.*" This connects with T7's past experience learning that their own TA was a Chinese speaker:

> "Because I feel like naturally I feel like more belonging and they can help me more ... I have more confidence in Chinese studying mathematics."

Relatedness

As described above, barriers toward fulfillment of relatedness needs included lack of safety, lack of community, and negative comparisons to peers. TA actions responded to relatedness needs by addressing each of these.

Students reported feeling safer as result of TA validation. Students indicated that having a TA lift them up promoted belonging (S3, S5, S9). T9 reflected on validation, saying,

> "I think the main thing with S9 is trying to make S9 feel like the questions that S9 is asking are okay, and that they're not too basic. ... I think your tone and the way you respond to somebody's questions are important."

T9's outlook on answering basic questions connected to their experience asking basic questions upon entering a CS Master's program with a humanities background. S9 found T9's validation to be helpful in that

> "T9 praised me on saying like, oh, like I actually asked really, like, deep questions, ... I feel like oh, wow. Like, my question is being valued, like my time is being valued."

When S5 was blaming themself for a problem with their code, a little validation from T5 went a long way:

> "T5 understood, like, right away. And T5 was like, Oh, this is like, totally fine. ... Thank god T5 understood. Because I was not feeling great. I was like, what is wrong with me?"

T5 reported familiarity with the danger of blaming students for language-related problems like S5's, saying,

> "There's a slight tendency sometimes to sort of fault the student for not, you know, keeping up with the language of the classroom. ... I just want to make sure like, you know, students aren't faulted for that. ... It's a common experience. And all it means is you just have to be careful about Unicode."

Another way of fulfilling the student need for safety was by students and TAs mutually building trusting relationships A TA could become familiar with a student's learning needs and build a relationship with the student over several office hour sessions (T2, T9), or based on knowing them from recitation section (T2) or previous course (T3). S9 and T9 described getting to know each other. T9 says,

> "I know S9 pretty well. ... S9 was one of those students who comes to every almost every office hour. ... S9 has even, like, sent me some emails, or at least an email before, basically thanking me for like, encouraging S9."

S9 describes coming to trust T9, saying,

> "I went to T9's very first office hour... I've established a relationship early on. So then there was this trust. ... I can be safe because I know I'm not being judged"

Participants indicated that to forge connections with students, it could help if the TA was warm, sociable, and shared personal experiences (S2, S6, S9, T4, T5). In S2's words,

> "TAs are not perfect either, you know they're also dealing with a lot of stress and just kind of knowing that that aspect of vulnerability just makes me feel more connected to them as a human being."

Both TAs and students indicated showing care supported student belonging (S2, S6, T7) Students described how TAs could show care by preparing and bringing their energy and engagement (S2, S6, S7, S9), and by using students' names (S2, S6, T7). According to S6,

> "Knowing people's names and using the name... it's a really great way to get people to feel a part of and heard and seen. ... People feel like you care."

They also reported it was helpful for TAs to show appropriate emotions. Not showing emotion or displaying annoyance, a bad mood, or coldness could harm student belonging (S2, S6, S9, T7), while warmth and a visible affect could help with student belonging (S2, S6, S9).

For S5, care in the form of T5's greeting brought relief from overwhelming nervousness about office hours. T5 described it as professionalism, saying,

> "I say, 'Hi, this is T5, from [CS2 for data science]. ... come to my Zoom[8] meeting, let me help you.' I think just at the bare minimum, it's just instructors, being polite to their students."

This simple act of introduction had a profound impact because it helped alleviate S5's anxiety. From S5's perspective,

> "Then I get help through the TA and you know, and then they greet me. And then I felt a little bit like, relieved. I was like, ha, yeah. I'm good."

One way TAs supported the student need for community, and through it their belonging, was by connecting with students. Participants inclined to connect with their TAs reported these connections could improve belonging, within limitations of professional distance between students and TAs. T5 reported such an experience with TA-led extra credit seminars and study sessions, saying

> "I did not recognize a single person who just came regularly to any of these except for the TA that was running the show. And so in a way, it just made me feel

[8]Zoom is a video call platform.

> more connected to the people who are running the show. ... The flip side of that is, the recognition of the TA community was something that I couldn't be part of anyways, because I was a student at the time, and they were TAs."

T7, who had connected with their own TAs and instructors, shared that they enjoyed forming connections with students but maintained professional distance by setting boundaries,

> "So these are the ways I feel like belonging is high. And like when students realize you actually care for them. And they would love to like be friends with them even just asking me, 'Hey, T7, how's your weekend?' Or like, follow me on Instagram or ask me out for dinner? I mean, that's kind of across the boundaries there. But I'm really happy even if I have to turn off their offer."

TAs also supported community formation by helping students meet peers. T3 described that they turned a corner in a difficult class after forming a study group with peers met in office hours, and afterward began to encourage their own students to collaborate. In T3's own words,

> "They're stuck on the same problem I'll just ask them, alright while I teach the other student, you guys can discuss and I'll come back to you in like several minutes when I'm done."

S7 shared that TA encouragement could be just what was needed to talk to peers, and expressed willingness to give up some autonomy for it. In S7's words,

> "Maybe like, force the student to get together to have conversations. ... I am not the... outgoing person that can speak to someone like near me. But if my TA would ask... I might feel willing to to talk with some other people. ... It will be weird, but for me is a suitable strategy."

S7 described an experience where complying with an icebreaker activity led to meeting peers who S7 then recognized in a different class the next academic term.

By getting to know peers, participants experienced greater academic success. Participants described that having friends could contribute to belonging by contributing to academic success (S4, S9, T7). For example, S4, whose CS1 study group formed from members of the Society of Hispanic Professional Engineers, said, "*I feel like I always do better when I work with people*," and S9 shared feeling encouraged not to skip class because of feeling missed by a friend in that class. T3 described how study groups improved their performance,

> "I started going to office hours and I started finding friends who were in the same position as me... weren't sure about how to approach each assignment then we will talk about it and work together and from a study group. And that made me from almost failing [probability and statistics] to getting a solid grade. ... Since that point I guess you can say that I have found my sense of belonging in CS."

TAs could help counter student tendencies toward negative, self-deprecating comparisons to peers by telling positive narratives about peers. S9 indicated it was helpful to receive advice on reframing negative comparisons. S9 described at first feeling intimidated when peers asked advanced questions, but the instructor offered another framing. In S9's words,

> "We cannot discount the amount of effort it took them to get here... everyone was once a beginner. Yeah. So then that kind of puts perspective into this. So that helps me feel better. ... He has grinded really hard to get to that point. And he deserves to ask that question. And that has nothing to do with my worth."

Participants described how TAs could offer reassurance to indicate the student was not alone because their struggle was shared by other students, the TA, or computer scientists in general (S3, S5, T4, T5, T7, T9). According to T9,

> "These issues that S9 was struggling with in this assignment, are actually things that real computer scientists, like I guess, myself also struggle with. ... You're dealing with the same problems as someone who belongs."

In contrast with negative self talk that students may be experiencing, they indicated positive narratives about one's peers could help to build feelings of commonality and belonging (S6, T3, T4, T5, T9). As T5 explained responding to a student's bug,

> "Just the acknowledgement of like, using different languages and different keyboards and stuff, being like, hey, I have a common experience with you. And this is something that a lot of other students have as well, even if you don't see it."

Autonomy

TAs supported student autonomy in office hours by explaining concepts to support student understanding and guiding students to discover answers, rather than giving away answers. Examples where TAs knew answers but did not give them away illustrate interplay between competence and autonomy in section 4.3.2. Furthermore, S9 and T9 shared an office hour in an advanced course. T9 described how there were many ways to solve the homework problem and T9 didn't ultimately get S9 to a solution; in the end, S9 was responsible for figuring it out. In T9's words,

> "I remember even being a little confused about what was happening in S9's code. ... But later, like S9 went away and figured out what S9 needed to do to make this work. I don't want to say it was based on the advice that I gave S9. It was probably mostly like S9's own experimentation."

From S9's perspective,

> "Once I kind of have a sense of what T9 is teaching me, I went back to solve the problem and it ended up me and [my friend in the course] figured out the solution."

Another way TAs supported student autonomy was by engaging on the student's own terms. T6 described getting the student's reasoning with,

> "Ask them questions, instead of talking. ... If you can get a student to explain the reasoning, you can figure out why they're confused. ... I think also gives students a chance to feel like their voices are heard."

An awareness of student autonomy connects to T6's experience of restricted autonomy, navigating family pressures to chart their academic course of study. T4 described letting students drive the interaction, a skill that they were working to improve, saying,

> "There were times when I found myself talking over S4 and then caught myself and stopped. ... I'm trying to do it less in office hours and sit in the silence and let them bring up questions."

S3 reported an increase in belonging when T3 engaged on S3's own terms, specifically,

> "T3 was really great, it's just asking, what's the problem? How do I do it, and reasoned through with what I was doing, acknowledging what I was doing wrong, and how I could fix it."

Chapter 5

DISCUSSION

When I asked students and TAs about their concepts of belonging, their stories, taken in aggregate, described satisfaction of the three psychological needs described in Self-Determination Theory: relatedness, competence, and autonomy. Some also surfaced the needs for safety and access as key components of belonging. TAs and students reported that TAs supported these needs by fostering understanding of the material, treating them with empathy, helping them to see peers positively, and helping them to own their own success.

Though not part of the initial analysis of the resubmission study, its results also connected to the basic needs of competence, relatedness, and autonomy. Resubmissions connected to the need for competence because of their influence on grades and learning: they encouraged students to read and learn from their feedback, took the pressure off the need to submit work that earned a perfect grade the first time, signalled an instructor focus on student learning, and simulated the problem solving competencies needed for professional practice. Resubmissions alone did not seem to make space for computer science identity and belonging, but other experiences did, for instance: experiences of autonomy such as open-ended projects and the ability to follow their own interests in special topics in CS; and experiences of relatedness such as collaboration and showing friends a website made in a programming assignment.

I believe my results are applicable outside the Allen School. To predict applicability to different contexts, the context of this work matters, including that UW is a large R1 research university where a plurality of students are white, and that the Allen School has large classes with many undergraduate TAs.

Some aspects of the belonging study's design limited its results. For example, this work did not systematically explore negative patterns of TA behavior around belonging. Furthermore, the paired nature of study participation, described to prospective participants from the start, means paired TAs and students were not anonymous to each other, despite careful protection of privacy outside pairs. This might have inhibited them from saying critical things about their counterpart. The study occurred in summer term, with smaller classes and less experienced lead instructors. However, curriculum and duration of term were the same as during the academic year and all returning TAs in the study had taught outside summer term. Furthermore, interview conversations encompassed participants' journeys of belonging beyond the bounds of the present academic term. The sample was weighted towards final-year

students, perhaps because of the summer term, or perhaps because of typical enrollment of courses I recruited from. Though researcher presence in office hours might have changed behavior of those observed, I mitigated this through non-invasive presence, described in section 4.2, and I used the observed office hour interactions to recruit interviewees, not as data for analysis.

There were also some limitations to the resubmission study. For instance, use of a researcher definition of belonging limits the scope of claims about belonging based on that study's results. In interviews, rather than asking questions using the term "belonging," the researchers asked participants what made them "feel like a computer scientist," and categorized their responses as pertaining to both belonging and CS identity. Using a researcher definition adds a level of consistency across participants, but ignores participants' own concepts of belonging. In contrast, the belonging study used participant concepts of belonging. Ordering of survey questions was also a limitation. The legacy course evaluation system employed by the University of Washington forced multiple choice questions to come before free answer questions, which allowed the possibility that answering the question about feedback could have biased students as they answered the free answer survey questions about reasons for resubmission.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
Middle School					✓				
Independent Study							✓		
High School AP	✓	✓		✓	✓				✓
High School Non-AP	✓	✓	✓		2	✓			✓

Table 5.1: Resubmissions study interview participants: CS before post-secondary education

	S2	S3	S4	S5	S6	S7	S9	T2	T3	T4	T5	T6	T7	T9
New	✓	✓	✓	✓		✓	✓	✓	✓		✓			✓
Experienced					✓					✓		✓	✓	

Table 5.2: Belonging study participants: Level of CS experience at the start of post-secondary education.

As with all qualitative research, the results of both studies are situated in their institutional and historical context as well as the context of their participants' identities. All study data

was collected during the COVID pandemic. For the resubmissions study in 2021, all courses and interviews were conducted virtually. The belonging study happened in 2022 with courses in person, and moderate support for virtual attendance, including some virtual office hours. Some belonging study interviews were in person and some were virtual. All interview participants were volunteers, potentially introducing self-selection bias. Tables 5.1 and 5.2 show the pre-college CS experience of interview participants. For the resubmissions study, I was surprised by the high levels of preparatory privilege. In the belonging study, I managed to recruit mostly students new to CS when they started their post-secondary education, which I believe better represents the population of the Allen School; however, recruiting pitches were designed to appeal on the basis of interest in inclusive practices, so it's likely the results represent participants with more clearly thought out ideas about belonging, including TAs more active in promoting belonging than average. As possibly an indicator of this, all TAs in the belonging study except one saw it as their responsibility to help students feel belonging.

Even accounting for these limitations, my work is broadly consistent with the psychological needs described in SDT as necessary for psychological wellbeing and autonomous motivation [20]. At university, belonging in a discipline could be construed as seeing it as a befitting course of study, which aligns with being motivated to study it. By this interpretation, the evidence suggests that in this context, belonging was more synonymous with motivation than with relatedness, even though SDT categorizes belonging as part of relatedness [20].

This might not be the case had I limited myself to a definition of belonging only encompassing relatedness, e.g. Josselson's 8 dimensions [37]. However, competence appears as a component of belonging in CS education [79]. Since an academic environment centers on students building their knowledge, and since a defensive climate, in which students form social hierarchies based on knowledge, is prominent in CS [8], competence could be understood as a context-specific example of the more general idea of "fit" with the environment and with others. Or, since many environments where one might belong focus on knowledge, it is possible that competence should be elevated as a component of belonging in its own right in trans-disciplinary definitions of belonging, such as Mahar's review of belonging [47].

Bringing in a structural framework, we can surpass the individual and interpersonal scope of human needs theories and understand the results of both studies as exposing need for structural change. Rankin et al. discuss how systems of oppression, such as exclusion of Black women from computing, play out through interpersonal interactions, for example, an instructor answering a question in a way that makes a Black woman student feel stupid [65]. In CS, those who feel they belong choose to continue, normalizing the culture that filtered for them in the first place. Without structural intervention, such discriminatory cycles will continue [80]. TAs in the belonging study said it was their personal responsibility to promote

belonging but not their job description. This suggests that the Allen School lacks effective structural policies to steer TA-student interpersonal interactions toward inclusion, and that the TAs in the study were acting individually. In this interpretation, my work exposes a need for structural change in the Allen School so that study TAs' personal outlooks on belonging can be enshrined more broadly and permanently. Another structural policy, which might get in the way of peer-to-peer interpersonal interactions between students, is the academic misconduct policy. Participants reported that collaboration and relationships helped promote belonging, but that they avoided those for fear of academic misconduct. This suggests that updating the Allen School's academic misconduct policy could lower barriers to belonging.

One important practical question about my results is why didn't the resubmissions study find a connection between belonging and resubmissions, despite the prediction that it would based on prior work? The over-representation of students with prior CS experience in the sample might explain this. In specific, if resubmissions influenced belonging for new CS learners, the study would have had little power to detect that. Another possible explanation is that the competitive climate in the Allen School CS program might have overshadowed any influence that resubmissions may have had on belonging. S4 recognized the importance of resubmissions toward learning, yet admitted to using them to improve grades more than for learning. Prioritizing grades over learning aligns with the Allen School's competitive CS major admissions, which at the time of the study considered CS2 grades. Relatedly, many Allen School courses shared an aggressive academic misconduct policy, and my results reveal that it discouraged students from collaobrating. Keeping in mind the finding that collaboration can increase belonging, it's possible that belonging losses from the misconduct policy could have overshadowed any belonging gains from the resubmission policy. Shortcomings in the implementation of the resubmissions model may have also masked any effects on belonging. In support of this interpretation, study participants reported confusion over their final grades and the possibility of earning a lower grade despite having mastered the material, both of which might become less likely as instructors polish their implementation of the same grading model over time. Finally, it is possible that even if executed well in an ideal institutional ecosystem, resubmissions alone may not be sufficient to support belonging. In support of this interpretation, most of the experiences students reported of resubmissions aligned with filling the need for competence, but not autonomy or relatedness. This would mean that something more is needed in addition to resubmissions, such as positive TA interactions.

My work suggests that individual TAs can support community formation, offer appropriate help with course work, and show kindness through validation to support student belonging. TAs might contribute to community formation by helping students meet each other and by being a friend to students, within professional boundaries. This aligns with prior work indicating university peers can be a source of academic and social support, leading to

belonging in CS [79]. In light of the fact that peer relationships are extra important for Black women [69] and that peers may exclude Black women from study groups [65], TAs might be especially attentive to inclusion of Black women and others from minoritized groups as they help build community. The results show nuance in guiding students through course work without giving away solutions or withholding information, and suggest TAs should take into account the course level and individual student needs to determine how much to give answers versus guidance. According to my data, when TAs respond with care, use names, lift students up, validate, and reassure, it can increase feelings of belonging, in alignment with hiring criteria expressed in [46], stating that TAs should be "empathetic toward struggling students." This suggests that kindness, not only academic support, is vital in TA behavior toward students.

Based on a structural interpretation of my results, it is important not only for TAs to behave individually in ways that promote belonging, but also for instructors and administrators to make structural change to promote belonging. Both approaches apply to the phenomenon of negative comparisons to peers, observed in my data. My results show that negative comparisons to peers, especially when based on exaggerated or imagined characteristics, can harm belonging. To address this phenomenon as imposter syndrome, TAs can support individuals experiencing it by mentoring them, helping them gain awareness of it, and pointing out they are not alone [64]. Or, to address this phenomenon as competitiveness of defensive climate, TAs might reign in experienced students' performances of academic prowess, value wrong answers as useful, and encourage students to see each other as collaborators, toward shifting the larger classroom climate [7]. Beyond the classroom, administrative structures can shape climate. For example, in the Allen School, judgment and competition imposed by administrators gatekeeping acceptance into the CS major set an example for students to view their peers competitively and judgmentally, while the academic misconduct policy causes fear about around interactions with peers over course work. By this interpretation, my results suggest a less competitive admissions system, such as lottery-based admissions [56], in tandem with relaxing of the academic misconduct policy, might reduce negative peer comparisons and help students feel a greater sense of belonging by forming collaborative relationships with peers.

To expand and perpetuate TA action that supports belonging, it is critical for instructors and administrators to hire and train TAs accordingly. Based on the results of my work, I challenge coalitions of TAs, faculty, CS department chairs, and policy makers to address these questions:

- Are TAs systematically trained about the importance of understanding each student's context to foster understanding and help individual students build CS competence?

- Are TAs hired based on social and emotional skills and trained in these skills to empathize and validate the struggles of students with widely varying personal and academic backgrounds?

- Are TAs hired based on their cultural assets that qualify them to support students who share those assets, such as first generation status and first language? Are diverse cohorts of TAs hired to leverage each unique TA's cultural assets toward effectively teaching and mentoring diverse groups of students?

As a start, I encourage instructors and academic leaders to implement TA trainings that address identity and belonging [55] and to reconsider their policies regarding student collaboration.

Beyond TA actions and course policy, prior work has identified many other facets of the student experience that influence belonging. Based on the results of prior work, these questions are also salient:

- Is decor of CS learning and community spaces selected with intention to avoid broadcasting stereotypes that have a gendered impact on belonging [17]?

- Does the CS curriculum include lessons about issues affecting marginalized students [80] and alternative narratives to stereotypes about computer scientists [45]?

- Do all belonging interventions take into account the power structures of race and gender [65]?

I hope that addressing these questions will be one step in a trend towards university CS programs placing a greater emphasis on promoting student sense of belonging, through policy, TA training, and more broadly, so that all CS students can truly feel like they belong.

BIBLIOGRAPHY

[1] TA Training Schedule. https://courses.cs.washington.edu/courses/ta-training/schedule/, August 2022.

[2] Othman Aljohani. A Comprehensive Review of the Major Studies and Theoretical Models of Student Retention in Higher Education. *Higher Education Studies*, 6(2):1, February 2016. ISSN 1925-475X, 1925-4741. doi:10.5539/hes.v6n2p1.

[3] Kelly-Ann Allen, Margaret L. Kern, Christopher S. Rozek, Dennis M. McInerney, and George M. Slavich. Belonging: A review of conceptual issues, an integrative framework, and directions for future research. *Australian Journal of Psychology*, 73(1):87–102, January 2021. ISSN 0004-9530. doi:10.1080/00049530.2021.1883409.

[4] Christine Alvarado, Mia Minnes, and Leo Porter. Micro-Classes: A Structure for Improving Student Experience in Large Classes. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, pages 21–26, Seattle Washington USA, March 2017. ACM. ISBN 978-1-4503-4698-6. doi:10.1145/3017680.3017727.

[5] Michael Ball, Andrew DeOrio, Justin Hsia, and Adam Blank. Teaching TAs to Teach: Strategies for TA Training. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, SIGCSE '21, pages 461–462, New York, NY, USA, March 2021. Association for Computing Machinery. ISBN 978-1-4503-8062-1. doi:10.1145/3408877.3432579.

[6] Albert Bandura. *Self-Efficacy: The Exercise of Control*. Macmillan, February 1997. ISBN 978-0-7167-2850-4.

[7] Lecia J. Barker, Melissa O'Neill, and Nida Kazim. Framing classroom climate for student learning and retention in computer science. In *Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, SIGCSE '14, pages 319–324, New York, NY, USA, March 2014. Association for Computing Machinery. ISBN 978-1-4503-2605-6. doi:10.1145/2538862.2538959.

[8] Lecia Jane Barker, Kathy Garvin-Doxas, and Michele Jackson. Defensive climate in the computer science classroom. *ACM SIGCSE Bulletin*, 34(1):43–47, February 2002. ISSN 0097-8418. doi:10.1145/563517.563354.

[9] Roy F. Baumeister and Mark R. Leary. The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, 117(3):497–529, 1995. ISSN 1939-1455, 0033-2909. doi:10.1037/0033-2909.117.3.497.

[10] Andrew Berns. Scored out of 10: Experiences with Binary Grading Across the Curriculum. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, SIGCSE '20, pages 1152–1157, New York, NY, USA, February 2020. Association for Computing Machinery. ISBN 978-1-4503-6793-6. doi:10.1145/3328778.3366956.

[11] Maureen Biggers, Tuba Yilmaz, and Monica Sweat. Using Collaborative, Modified Peer Led Team Learning To Improve Student Success and Retention in Intro CS. In *SIGCSE 09*, page 5, Chatanooga, TN, 2009. ACM.

[12] Kathryn Bridson, Jeffrey Atkinson, and Scott D. Fleming. Delivering Round-the-Clock Help to Software Engineering Students Using Discord: An Experience Report. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1*, SIGCSE 2022, pages 759–765, New York, NY, USA, February 2022. Association for Computing Machinery. ISBN 978-1-4503-9070-5. doi:10.1145/3478431.3499385.

[13] Urie Bronfenbrenner. Toward an experimental ecology of human development. *American Psychologist*, 32:513–531, 1977. ISSN 1935-990X. doi:10.1037/0003-066X.32.7.513.

[14] Shearon Brown and Xiaohong Yuan. Experiences with Retaining Computer Science Students. In *CCSC: Mid-South Conference*, page 8. Consortium for Computing Sciences in Colleges, 2014.

[15] Kelsey Chamberlin, Maï Yasué, and I-Chant Andrea Chiang. The impact of grades on student motivation. *Active Learning in Higher Education*, page 1469787418819728, December 2018. ISSN 1469-7874. doi:10.1177/1469787418819728.

[16] Qiong Cheng, David Benton, and Andrew Quinn. Building a Motivating and Autonomy Environment to Support Adaptive Learning. In *2021 IEEE Frontiers in Education Conference (FIE)*, pages 1–7, October 2021. doi:10.1109/FIE49875.2021.9637397.

[17] Sapna Cheryan, Victoria C. Plaut, Paul G. Davies, and Claude M. Steele. Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology*, 97(6):1045–1060, 2009. ISSN 1939-1315, 0022-3514. doi:10.1037/a0016239.

[18] Tanya Covic and Mairwen K. Jones. Is the essay resubmission option a formative or a summative assessment and does it matter as long as the grades improve? *Assess-*

ment & Evaluation in Higher Education, 33(1):75–85, February 2008. ISSN 0260-2938. doi:10.1080/02602930601122928.

[19] John W. Creswell and Cheryl N. Poth. *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications, December 2016. ISBN 978-1-5063-3019-8.

[20] Edward L. Deci and Richard M. Ryan. The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, 11(4): 227–268, October 2000. ISSN 1047-840X. doi:10.1207/S15327965PLI1104_01.

[21] Adrienne Decker, Phil Ventura, and Christopher Egert. Through the looking glass: Reflections on using undergraduate teaching assistants in CS1. In *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education*, SIGCSE '06, pages 46–50, New York, NY, USA, March 2006. Association for Computing Machinery. ISBN 978-1-59593-259-4. doi:10.1145/1121341.1121358.

[22] Paul E. Dickson, Toby Dragon, and Adam Lee. Using Undergraduate Teaching Assistants in Small Classes. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, SIGCSE '17, pages 165–170, New York, NY, USA, March 2017. Association for Computing Machinery. ISBN 978-1-4503-4698-6. doi:10.1145/3017680.3017725.

[23] Francisco J. Estrada and Anya Tafliovich. Bridging the Gap Between Desired and Actual Qualifications of Teaching Assistants: An Experience Report. In *Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education*, ITiCSE '17, pages 134–139, New York, NY, USA, June 2017. Association for Computing Machinery. ISBN 978-1-4503-4704-4. doi:10.1145/3059009.3059023.

[24] Beverly S. Faircloth and Jill V. Hamm. Sense of Belonging Among High School Students Representing 4 Ethnic Groups. *Journal of Youth and Adolescence*, 34(4):293–309, August 2005. ISSN 0047-2891, 1573-6601. doi:10.1007/s10964-005-5752-7.

[25] Tierra M. Freeman, Lynley H. Anderman, and Jane M. Jensen. Sense of Belonging in College Freshmen at the Classroom and Campus Levels. *The Journal of Experimental Education*, 75(3):203–220, April 2007. ISSN 0022-0973. doi:10.3200/JEXE.75.3.203-220.

[26] Kathy Garvin-Doxas and Lecia J. Barker. Communication in computer science classrooms: Understanding defensive climates as a means of creating supportive behaviors. *Journal on Educational Resources in Computing*, 4(1):2–es, March 2004. ISSN 1531-4278. doi:10.1145/1060071.1060073.

[27] Seyed-Arman Ghaffari-Zadeh and Gerald Wang. Fishers Handle Bugs Better than Fish-Receivers: Nourishing Computational Self-Efficacy in Engineering Coursework. In *American Society for Engineering Education 2022 Annual Conference*, Minneapolis, MN, USA, 2022.

[28] Cari Gillen-O'Neel. Sense of Belonging and Student Engagement: A Daily Study of First- and Continuing-Generation College Students. *Research in Higher Education*, 62 (1):45–71, 2019. ISSN 1573-188X. doi:10.1007/s11162-019-09570-y.

[29] Girls Who Code. About Us. https://girlswhocode.com/about-us.

[30] William Glasser. *Control Theory in the Classroom*. Perennial Library, 1986. ISBN 978-0-06-055015-8.

[31] William Glasser and Pauline B. Gough. The Key to Improving Schools: An Interview with William Glasser. *The Phi Delta Kappan*, 68(9):656–662, 1987. ISSN 0031-7217.

[32] Carol Goodenow. Classroom Belonging among Early Adolescent Students: Relationships to Motivation and Achievement. *The Journal of Early Adolescence*, 13(1):21–43, February 1993. ISSN 0272-4316. doi:10.1177/0272431693013001002.

[33] Carol Goodenow. The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools*, 30(1):79–90, January 1993. ISSN 00333085, 15206807. doi:10.1002/1520-6807(199301)30:1<79::AID-PITS2310300113>3.0.CO;2-X.

[34] Bonnie M. K. Hagerty and Kathleen Patusky. Developing a Measure Of Sense of Belonging. *Nursing Research*, 44(1):9–13, January 1995. ISSN 0029-6562.

[35] David Hammer and Leema K. Berland. Confusing Claims for Data: A Critique of Common Practices for Presenting Qualitative Research on Learning. *Journal of the Learning Sciences*, 23(1):37–46, January 2014. ISSN 1050-8406. doi:10.1080/10508406.2013.802652.

[36] David Hammer and Leema K Berland. Confusing claims for data: A critique of common practices for presenting qualitative research on learning. *Journal of the Learning Sciences*, 23(1):37–46, 2014.

[37] Ruthellen Josselson. *The Space between Us: Exploring the Dimensions of Human Relationships*. Sage, 1996.

[38] Ruthellen Josselson. The Space Between in Group Psychotherapy: Application of a Multidimensional Model of Relationship. *Group*, 27(4):203–219, 2003. ISSN 0362-4021.

[39] Peter Kugel. How professors develop as teachers. *Studies in Higher Education*, 18(3): 315–328, January 1993. ISSN 0307-5079, 1470-174X. doi:10.1080/03075079312331382241.

[40] Chen-Lin C. Kulik, James A. Kulik, and Robert L. Bangert-Drowns. Effectiveness of mastery learning programs: A meta-analysis. *Review of Educational Research*, 60(2): 265–299, 1990. doi:10.3102/00346543060002265.

[41] Anael Kuperwajs Cohen. *Factors Influencing the Social Help-Seeking Behavior of Introductory Programming Students*. PhD thesis, Macalester College, April 2021.

[42] Noel LeJeune. Contract grading with mastery learning in CS 1. *Journal of Computing Sciences in Colleges*, 26(2):149–156, December 2010. ISSN 1937-4771.

[43] Colleen Lewis, Paul Bruno, Jonathan Raygoza, and Julia Wang. Alignment of Goals and Perceptions of Computing Predicts Students' Sense of Belonging in Computing. In *Proceedings of the 2019 ACM Conference on International Computing Education Research*, ICER '19, pages 11–19, New York, NY, USA, July 2019. Association for Computing Machinery. ISBN 978-1-4503-6185-9. doi:10.1145/3291279.3339426.

[44] Colleen M. Lewis, Ken Yasuhara, and Ruth E. Anderson. Deciding to major in computer science: A grounded theory of students' self-assessment of ability. In *Proceedings of the Seventh International Workshop on Computing Education Research*, ICER '11, pages 3–10, New York, NY, USA, August 2011. Association for Computing Machinery. ISBN 978-1-4503-0829-8. doi:10.1145/2016911.2016915.

[45] Colleen M. Lewis, Ruth E. Anderson, and Ken Yasuhara. "I Don't Code All Day": Fitting in Computer Science When the Stereotypes Don't Fit. In *Proceedings of the 2016 ACM Conference on International Computing Education Research*, ICER '16, pages 23–32, New York, NY, USA, August 2016. Association for Computing Machinery. ISBN 978-1-4503-4449-4. doi:10.1145/2960310.2960332.

[46] Dan Leyzberg, Jérémie Lumbroso, and Christopher Moretti. Nailing the TA Interview: Using a Rubric to Hire Teaching Assistants. In *Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education*, pages 128–133, Bologna Italy, June 2017. ACM. ISBN 978-1-4503-4704-4. doi:10.1145/3059009.3059057.

[47] Alyson L. Mahar, Virginie Cobigo, and Heather Stuart. Conceptualizing belonging. *Disability and Rehabilitation*, 35(12):1026–1032, June 2013. ISSN 0963-8288. doi:10.3109/09638288.2012.717584.

[48] Julia M. Markel and Philip J. Guo. Inside the Mind of a CS Undergraduate TA: A Firsthand Account of Undergraduate Peer Tutoring in Computer Labs. In *Proceedings*

of the 52nd ACM Technical Symposium on Computer Science Education, SIGCSE '21, pages 502–508, New York, NY, USA, March 2021. Association for Computing Machinery. ISBN 978-1-4503-8062-1. doi:10.1145/3408877.3432533.

[49] A. H. Maslow. A theory of human motivation. *Psychological Review*, 50(4):370–396, July 1943. ISSN 1939-1471, 0033-295X. doi:10.1037/h0054346.

[50] Mia Minnes. Designing TA Training for Computer Science Graduate Students: Remote and Self-paced Options for A Supported Introduction to Reflective Teaching. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1*, SIGCSE 2022, pages 752–758, New York, NY, USA, February 2022. Association for Computing Machinery. ISBN 978-1-4503-9070-5. doi:10.1145/3478431.3499342.

[51] Diba Mirza, Phillip T. Conrad, Christian Lloyd, Ziad Matni, and Arthur Gatin. Undergraduate Teaching Assistants in Computer Science: A Systematic Literature Review. In *Proceedings of the 2019 ACM Conference on International Computing Education Research*, ICER '19, pages 31–40, New York, NY, USA, July 2019. Association for Computing Machinery. ISBN 978-1-4503-6185-9. doi:10.1145/3291279.3339422.

[52] Catherine Mooney, Anna Antoniadi, Ioannis Karvelas, Lána Salmon, and Brett A. Becker. Exploring Sense of Belonging in Computer Science Students. In *Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education*, ITiCSE '20, page 563, New York, NY, USA, June 2020. Association for Computing Machinery. ISBN 978-1-4503-6874-2. doi:10.1145/3341525.3393974.

[53] Linda B. Nilson. *Specifications Grading: Restoring Rigor, Motivating Students, and Saving Faculty Time*. Stylus Publishing, LLC, March 2015. ISBN 978-1-62036-244-0.

[54] Claudia Ott, Brendan McCane, and Nick Meek. Five years of Mastery Learning: What did we learn? In *Proceedings of the 18th Koli Calling International Conference on Computing Education Research*, Koli Calling '18, pages 1–2, New York, NY, USA, November 2018. Association for Computing Machinery. ISBN 978-1-4503-6535-2. doi:10.1145/3279720.3279752.

[55] Becky Wai-Ling Packard and Mount Holyoke College Computer Science Department. AIICE Professional Development for TAs - Topics. https://sites.google.com/mtholyoke.edu/aiice-ta-workshop/topics.

[56] Jordan Packer. The CSE Powerball, October 2017.

[57] Elizabeth Patitsas. A case study of environmental factors influencing teaching assistant job satisfaction. In *Proceedings of the Ninth Annual International Conference on*

International Computing Education Research, ICER '12, pages 11–16, New York, NY, USA, September 2012. Association for Computing Machinery. ISBN 978-1-4503-1604-0. doi:10.1145/2361276.2361280.

[58] Elizabeth Patitsas. A case study of the development of CS teaching assistants and their experiences with team teaching. In *Proceedings of the 13th Koli Calling International Conference on Computing Education Research - Koli Calling '13*, pages 115–124, Koli, Finland, 2013. ACM Press. ISBN 978-1-4503-2482-3. doi:10.1145/2526968.2526981.

[59] Leah Perlmutter, Jayne Everson, Ken Yasuhara, Brett Wortzman, and Kevin Lin. Poster: Reading Between the Lines: Student Experiences of Resubmission in an Introductory CS Course. In *SIGCSE 2022*, page 2, Providence, Rhode Island, 2022.

[60] Leah Perlmutter, Jean Salac, and Amy J. Ko. "A field where you will be accepted": Belonging in student and TA interactions in post-secondary CS education. In *Proceedings of the 2023 ACM Conference on International Computing Education Research*, Chicago, IL, USA, August 2023. Association for Computing Machinery. ISBN 978-1-4503-9976-0. doi:10.1145/3568813.3600128.

[61] Laura D. Pittman and Adeya Richmond. Academic and Psychological Functioning in Late Adolescence: The Importance of School Belonging. *The Journal of Experimental Education*, 75(4):270–290, 2007. ISSN 0022-0973.

[62] Laura D. Pittman and Adeya Richmond. University Belonging, Friendship Quality, and Psychological Adjustment During the Transition to College. *The Journal of Experimental Education*, 76(4):343–362, July 2008. ISSN 0022-0973. doi:10.3200/JEXE.76.4.343-362.

[63] Inna Pivkina. Peer learning assistants in undergraduate computer science courses. In *2016 IEEE Frontiers in Education Conference (FIE)*, pages 1–4, October 2016. doi:10.1109/FIE.2016.7757658.

[64] Elizabeth Ramsey and Deana Brown. Feeling like a fraud: Helping students renegotiate their academic identities. *College & Undergraduate Libraries*, 25(1):86–90, January 2018. ISSN 1069-1316, 1545-2530. doi:10.1080/10691316.2017.1364080.

[65] Yolanda A. Rankin, Jakita O. Thomas, and Sheena Erete. Real Talk: Saturated Sites of Violence in CS Education. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, SIGCSE '21, pages 802–808, New York, NY, USA, March 2021. Association for Computing Machinery. ISBN 978-1-4503-8062-1. doi:10.1145/3408877.3432432.

[66] Emma Riese and Viggo Kann. Training Teaching Assistants by Offering an Introductory Course. In *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1*, SIGCSE 2022, pages 745–751, New York, NY, USA, February 2022. Association for Computing Machinery. ISBN 978-1-4503-9070-5. doi:10.1145/3478431.3499270.

[67] Emma Riese, Madeleine Lorås, Martin Ukrop, and Tomáš Effenberger. Challenges Faced by Teaching Assistants in Computer Science Education Across Europe. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1*, pages 547–553, New York, NY, USA, June 2021. Association for Computing Machinery. ISBN 978-1-4503-8214-4.

[68] Sarah L. Rodriguez and Kathleen Lehman. Developing the next generation of diverse computer scientists: The need for enhanced, intersectional computing identity theory. *Computer Science Education*, 27(3-4):229–247, October 2017. ISSN 0899-3408. doi:10.1080/08993408.2018.1457899.

[69] Monique Ross, Zahra Hazari, Gerhard Sonnert, and Philip Sadler. The Intersection of Being Black and Being a Woman: Examining the Effect of Social Computing Relationships on Computer Science Career Choice. *ACM Transactions on Computing Education*, 20(2):9:1–9:15, February 2020. doi:10.1145/3377426.

[70] Johnny Saldana. *The Coding Manual for Qualitative Researchers*. SAGE, third edition, 2015.

[71] Christopher D. Slaten, Jonathan K. Ferguson, Kelly-Ann Allen, Dianne-Vella Brodrick, and Lea Waters. School Belonging: A Review of the History, Current Trends, and Future Directions. *The Educational and Developmental Psychologist*, 33(1):1–15, July 2016. ISSN 2059-0776, 2059-0784. doi:10.1017/edp.2016.6.

[72] Jo Sprague and Jody D. Nyquist. TA Supervision. *Teaching assistant training in the 1990s*, pages 37–53, 1989.

[73] Scott Spurlock. Improving Student Motivation by Ungrading. In *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, pages 631–637, Toronto ON Canada, March 2023. ACM. ISBN 978-1-4503-9431-4. doi:10.1145/3545945.3569747.

[74] Robert Talbert. Specifications grading: We may have a winner. http://rtalbert.org/specs-grading-iteration-winner/, April 2017.

[75] Mina Tari and Hala Annabi. Someone On My Level: How Women of Color Describe the Role of Teaching Assistants in Creating Inclusive Technology Courses. *AMCIS 2018 Proceedings*, August 2018.

[76] Mina Tari, Hala Annabi, and Andrew Ko. Understanding Undergraduate Teaching Assistants' Perspectives on Inclusive Pedagogy in Introductory Computing Courses. In *2019 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*, pages 1–2, February 2019. doi:10.1109/RESPECT46404.2019.8985811.

[77] Mina Tari, Vivian Hua, Lauren Ng, and Hala Annabi. How Asian Women's Intersecting Identities Impact Experiences in Introductory Computing Courses. In Katharina Toeppe, Hui Yan, and Samuel Kai Wah Chu, editors, *Diversity, Divergence, Dialogue*, pages 603–617, Cham, 2021. Springer International Publishing. ISBN 978-3-030-71292-1. doi:10.1007/978-3-030-71292-1_47.

[78] Vincent Tinto. *Leaving College: Rethinking the Causes and Cures of Student Attrition*. University of Chicago Press, 1993. ISBN 978-0-226-80449-1.

[79] Nanette Veilleux, Rebecca Bates, Cheryl Allendoerfer, Diane Jones, Joyous Crawford, and Tamara Floyd Smith. The relationship between belonging and ability in computer science. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education*, SIGCSE '13, pages 65–70, New York, NY, USA, March 2013. Association for Computing Machinery. ISBN 978-1-4503-1868-6. doi:10.1145/2445196.2445220.

[80] Alicia Nicki Washington. When Twice as Good Isn't Enough: The Case for Cultural Competence in Computing. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*, SIGCSE '20, pages 213–219, New York, NY, USA, February 2020. Association for Computing Machinery. ISBN 978-1-4503-6793-6. doi:10.1145/3328778.3366792.

[81] Robbie Weber. Using Alternative Grading in a Non-Major Algorithms Course. In *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1*, pages 638–644, Toronto ON Canada, March 2023. ACM. ISBN 978-1-4503-9431-4. doi:10.1145/3545945.3569765.