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RETENTION OF WOMEN IN COMPUTER SCIENCE: WHY WOMEN PERSIST IN THEIR COMPUTER SCIENCE MAJORS

by

Katarina Pantic

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Instructional Technology and Learning Sciences

Approved:

Jody Clarke-Midura, Ed.D. Major Professor	Sherry Marx, Ph.D. Committee Member
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UTAH STATE UNIVERSITY
Logan, Utah

2020

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ABSTRACT

Retention of Women in Computer Science: Why Women Persist in Their Computer Science Majors

by

Katarina Pantic, Doctor of Philosophy

Utah State University, 2020

Major Professor: Jody Clarke-Midura, Ed.D.
Department: Instructional Technology and Learning Sciences

Retention of women through graduation in Computer Science (CS) majors is one of the biggest challenges for CS education. Most research in this area focuses on factors influencing attrition rather than why and how women remain committed. The goal of this research study is to understand retention from the perspective of women who persisted in their CS major. Using the theoretical lens of legitimate peripheral participation in communities of practice, I designed and conducted a study that involved focus groups, interviews, journey maps, and experience sampling methods. I found that retention of women in this study was influenced by four different types of interactions and eight different practices inside the CS major. I also found that learning was a matter of multimembership at the intersection of several different communities which supported both these women's learning and retention. Finally, this dissertation provides a cross-case study narrative that highlights commonalities and differences of different pathways of

ongoing participation investigated in this study. Such narrative is illustrated by five individual case studies of five women persisting in their CS major.

(276 pages)

PUBLIC ABSTRACT

Retention of Women in Computer Science: Why Women Persist in Their Computer Science Majors

Katarina Pantic

Retention of women through graduation in Computer Science (CS) majors is one of the biggest challenges for CS education. Most research in this area focuses on factors influencing attrition rather than why and how women remain committed. The goal of this research study is to understand retention from the perspective of women who persisted in their CS major. Using the theoretical lens of legitimate peripheral participation in communities of practice, I designed and conducted a study that involved focus groups, interviews, journey maps, and experience sampling methods. I found that retention of women in this study was influenced by four different types of interactions and eight different practices inside the CS major. I also found that learning was a matter of multimembership at the intersection of several different communities which supported both these women's learning and retention. Finally, this dissertation provides a cross-case study narrative that highlights commonalities and differences of different pathways of ongoing participation investigated in this study. Such narrative is illustrated by five individual case studies of five women persisting in their CS major.

DEDICATION

I dedicate this dissertation to my family: my mother, for always insisting on the importance of education, and my brother, Aleksandar, for being an infinite source of love and encouragement throughout the years of my schooling.

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First and foremost, I would like to thank Dr. Jody Clarke-Midura, my advisor and dissertation chair, for all the patience, support and thoughtful feedback throughout this process. You have shaped me as a scholar, and you built my self-confidence. For that and your immense friendship, I am eternally grateful.

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Finally, I feel immense appreciation for my partner, Tedy Anderson, for supporting me throughout the most challenging moments of working on this study. Thank you!

Katarina Pantic

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CHAPTER I

INTRODUCTION

Women comprise 51% of the population (Wasburn & Miller, 2006) in the US and earn 57% of the baccalaureate degrees overall (National Science Foundation [NSF], 2018). In Computer Science (CS) education, however, women have been glaringly underrepresented. In 2016-17, only 30% of the Computer Science Principles and 23% of the Computer Science A Advanced Placement (AP) Exam test-takers were female (College Board, 2018), with some states, such as Wyoming and Montana, recording less than five female test-takers on either of those two exams. In college, women earn only about 18.7% of the CS baccalaureate degrees (NSF, 2019). According to the same source, LatinX women make 1.86% of students graduating with a CS baccalaureate degree, African American/Black 2.19%, and Asian/Asian American 2.84%.

The number of women in CS has been on a constant decline from the 1990s and it is currently at its historic low (Iskander et al., 2013), lower than in any other STEM field (Ashcraft et al., 2012). Despite the fact that the field has recorded an overall increase in undergraduate enrollment (74% from 2009 to 2015; Computing Research Association, 2016; National Academies of Sciences, Engineering, Medicine, 2017) (21.8% from 2014 to 2015 alone; Zweben & Bizot, 2016), the overall percentage of women has remained the same in the last decade (Computing Research Association, 2016; National Academies of Sciences, Engineering, Medicine, 2017). As an example, a recent study from a large public university confirmed that there still was a significant gender gap inside their CS majors (Babes-Vroman et al., 2017). This gap was close to the national average and was

neither narrowing nor growing based on their data. Similarly, a report based on surveys from 178 national Ph.D. granting universities in the US, found that only 15.7% of baccalaureate degrees in CS in 2015 were awarded to women (Zweben & Bizot, 2016). At some universities in Utah, the situation is even more dire. The percentage of women in CS undergraduate studies is 11% to 15% [personal communication], which is lower than the national average. Such statistics make this region a context ripe for inquiry.

Problem Statement

In general, underrepresentation of women in CS is problematic for a variety of reasons. For one, gender misbalance is unethical (Wilson, 2002) as it creates a socially inequitable field (Miliszewska et al., 2006; Trauth, 2011), one where the best paid and most employable professions (U.S. Bureau of Labor Statistics, 2015, 2018) are available primarily to one gender. Next, gender misbalance translates into lost opportunities for women (Cuny & Aspray, 2002). As computing itself is becoming increasingly pervasive in our everyday lives (Aspray et al., 2006) and professions are becoming increasingly "hybrid" (i.e., they contain more and more computing components; Lohr, 2009), women who do not possess computer-related skills are at an immediate disadvantage. Development of such skills allows one to deal with daily technical demands both professionally and personally (Crow, 2014; Vee, 2013). Third, gender misbalance deprives the field itself of necessary diversity, which is important for the competitiveness of the field (Ashcraft et al., 2012; Wilson, 2002), but also so the diverse consumer is represented in the production process (Trauth, 2011). There are many examples of how

women's needs have been overlooked in the production. As an example, Fitbit launched a Female Health feature on their app which allowed women to log their periods only if the period lasted for 10 days or less, demonstrating lack of understanding of female bodies (Curtis, 2018). Margolis and Fisher (2003) highlight another example, the voice recognition software, which does not hear female voices accurately, pointing out that technology is not always tested on female users. Finally, gender misbalance creates a lot of societal losses: when women are absent, the society loses on creativity, knowledge, discourse (Barton et al., 2008; Cuny & Aspray, 2002), valuable perspectives (Ashcraft et al., 2012) and innovations women could generate if they were active participants in this field (DuBow, 2013; Schnabel, 2013).

It is important to emphasize that the problem of underrepresentation of women in CS education field is twofold (Wilson, 2002). In addition to low recruitment rates, there is also the problem of retention. The problem of retention is the most prominent during the first two years of being in the program, when attrition rates are highest (Biggers et al., 2008; Miliszewska et al., 2006; Stephenson et al., 2018). As much as 26.6% of already low numbers of Freshmen and 22.2% of Sophomore women drop out of their CS major during those two years (Stephenson et al., 2018).

To resolve the problem of retention, we need a better understanding of the process itself. Currently, there is a significant amount of research done on retention overall. However, most of it examines the phenomenon by focusing on factors weakening women's commitment to the major (e.g., Roberts et al., 2012; Urliksen et al., 2015), which is problematic as factors influencing retention may be different from factors

influencing attrition (Cheryan et al., 2011). Studies that examine women who persist in this major (e.g., Dee et al., 2009; DuBow et al., 2017; Ragsdale, 2013; Rosson et al., 2011; Wilson, 2002) are rare.

Dissertation Goal

The primary goal of this research study is, therefore, to acquire a better understanding of retention of women in CS major from the perspective of women who have persisted in this major. More specifically, this study investigates the practices contributing to the persistence of women in the major, the resources and support available to them, the communities of practice (CoPs)that they belong to in addition to their major, and some participation pathways of members with proven ongoing participation.

Objectives

To that end, this project will meet three objectives.

1. To investigate different factors that influence persistence of women in CS majors, with additional emphasis on social interactions and practices that enable such persistence.
2. To inquire about other communities the women are a part of, as well as how those are connected to their persistence in the program.
3. To explore different pathways that women follow as they engage in the social practice of their major.

It is important to clarify at this point that pathways here refer to women's participation in key practices and interactions of the major, which helped them develop full understanding of the CoP and participate fully in that major (Lemke, 1997). The word "pathways" is used to distinguish them from trajectories as they are defined by Wenger (1998b) who focuses on identity formation, while the focus of this dissertation is

on ongoing participation alone.

Research Questions

To accomplish these objectives, this study will address the following research questions:

1. Which factors (i.e., enablers) influence women's ongoing participation (i.e., retention) in their CS majors?
    a. Which interactions and practices influence women to persist in their CS majors?
2. What other communities do they belong to as they work towards the completion of their major that support their retention?
3. What different participation pathways do women follow as they work towards the completion of their major?

Significance of This Study

Research on retention of women in CS is a newer research topic with a vast majority of existing studies taking a quantitative approach (see Pantic & Clarke-Midura, 2019). Existing research rarely focuses on the voice of women persisting in their CS majors or the uniqueness of their experience. Rather than focusing on women who leave CS and the factors influencing departure, this study aims to gain better understanding of the factors influencing the process of persistence in the CS major. Another contribution of this study is the use of a recognized learning theory to explain retention. By focusing on women's individual participation pathways throughout the major, this study has the potential to gain insight into the dynamic of legitimate peripheral participation (LPP) of women as they get socialized into the CoPs of their CS major. Next, the use of a more

holistic approach, through a combination of experience sampling, in-depth interviews, journey maps and focus groups, allowed me to provide a better description of the complexity of the ongoing participation with practices and interactions influencing persistence, as well as if and how they are interdependent. Finally, this study investigates which CoPs, if any, in addition to their CS major, support persistence of women in CS majors. Ideally, the data generated in this study will lead to extracting a set of principles for keeping women in CS, or alternatively, helping them succeed in this male-dominated major.

Definition of Terms

Communities of Practice (CoP) are social configurations formed by "people who engage in the process of collective learning within a shared domain of" interest (Wenger-Trayner, 2015, p. 1).

Legitimate Peripheral Participation (LPP) is a fundamental form of learning (Lave & Wenger, 1991). It implies the process of becoming a different person through participation in a CoP and in connection to the possibilities, resources and support within and enabled by the CoP one is engaging in.

Multimembership is defined as participation across different CoPs where the goal is to develop true mastery of practice (Lemke, 1997).

Retention of women in CS is defined in this study as a proven intention of female students to complete their CS major. This means that they passed the critical period of first two years (Cohoon, 2001; Frieze et al., 2012; Miliszewska et al., 2006) in the

program, and have reached the status of upperclassmen (Junior or Senior), or have ideally, graduated from the program.

Underrepresentation in this study refers to a low number of women in CS.

Summary

Considering that CS is one of the fastest growing fields, the glaring underrepresentation of women in CS is problematic for a number of individual, ethical and societal reasons. Underrepresentation, however, is a twofold problem. The aim of this dissertation is to acquire a better understanding of retention, independently from recruitment, from the perspective of women who persisted in this major using LPP in CoP as a theoretical framework. More specifically, this study investigates those practices and interactions that contributes to the persistence of women in the major, as well as resources and support that were available to them throughout their CS journey. At the same time, the study examined different CoPs that participants belonged to while working on their CS major, as well as how their individual participation looked like for the duration of their studies.

Dissertation Outline

This dissertation study follows a five-chapter format, which includes an introduction, a review of relevant literature, methods, study findings, and a discussion and conclusion section. In Chapter I, I describe the background of the issue that I am exploring and the problem statement. I also lay out the primary goal, objectives and

research questions of my dissertation, and define the key terms used. Chapter II synthesizes relevant literature on retention of women in CS (i.e., factors influencing retention and attrition, as well as on interventions designed to improve retention of women in this major and the state of retention of women in CS across the globe). This chapter ends in providing a review of literature on the theoretical framework I am using in this study, which is LPPin CoPs. In Chapter III, I describe the research design selected for this study, which includes recruitment and sampling strategies, as well as a description of data collection and data analysis. Chapter IV reports the results of this study by research question, preceded by demographic information of the sample. Finally, in Chapter V, I discuss the findings presented in Chapter IV in light of the theoretical perspective and previous literature described in Chapter II. This chapter also includes the contributions of the dissertation study, its limitations, and recommendations for future research.

CHAPTER II

REVIEW OF LITERATURE[1]

Factors Influencing Computer Science Retention of Women in the U.S.

After conducting a systematic literature review (see Pantic & Clarke-Midura, 2019), we found that research approaches to investigating retention of women in CS have changed over the years. Initially, research focused on gender differences between male and female students in CS. Later, researchers shifted their focus to examining the role of institutional factors on retention. In addition to these two bodies of research, studies occasionally investigated a variety of factors external to the institution, such as family support or cultural norms and values. The following sections provide an overview of literature on the three bodies of literature identified in this search, which we grouped as individual, institutional, and external factors inspired by Tinto's (1987) Model of Institutional Departure.

Individual Factors

Research focusing on gender differences revealed a variety of individual or personal factors that influence retention of women in CS. From this line of inquiry, which mostly explored gender differences, we learn that when compared to their male cohorts, women lacked prior experience in programming, and had different participation patterns and self-perceptions. This section further explains each of these categories in detail.

[1] Portions of this literature review were included in: Pantic, K., & Clarke-Midura, J. (2019). Factors that influence retention of women in the computer science major: A systematic literature review. *Journal of Women and Minorities in Science and Engineering 25(2), 119–145.* Reprinted with Permission (see Appendix J).

Prior Experience

One of the most frequently mentioned gender differences in literature is that women enrolling into CS majors had far less computer (Denner et al., 2014; Gürer & Camp, 2002; Margolis & Fisher, 2003; Margolis et al., 2000) and programming experience (Liu & Blanc, 1996; Ragsdale, 2013; Staehr et al., 2000) in comparison to their male cohorts. They also reported using computers much less overall (Clegg & Trayhurn, 2000), and or having less background knowledge on computers and programming (Liu & Blanc, 1996; Roberts et al., 2012). Consequently, women often reported feeling overwhelmed and intimidated by both programming and CS terminology in their introductory CS classes (Liu & Blanc, 1996; Roberts et al., 2012). Lack of prior experience was not only found to negatively affect women's confidence and comfort in the program (Margolis & Fisher, 2003), but it was also found to be a big hindrance to retention (Buzzetto-More et al., 2010) and a big predictor of attrition (Katz et al., 2006) and or failure in CS courses taken (Staehr et al., 2000). On the other hand, high technical skills and high emotional intelligence were found to increase women's satisfaction with their CS major (Lewis et al., 2008), while Milesi et al. (2017) found that feelings of being skilled in the CS were positively associated with persistence of women in CS. In their study of 200 students in introductory CS courses at the University of Pittsburgh, Katz et al. (2006) found that level of women's prior experience was not connected to their success in introductory CS classes. As a matter of fact, women with low prior experience outperformed women with high exposure to programming.

Participation Patterns

Second, some studies on gender gap in CS majors found that women exhibited different participation patterns in comparison to their male cohort. In the beginning of their CS major, women often reported feeling uncomfortable (Liu & Blanc, 1996; Staehr et al., 2000; Wilson, 2002), but were found to get more interested as the program progressed (Frieze et al., 2012). As some of the reasons for feeling uncomfortable, some research suggested that women had different intellectual preferences in comparison to men, which resulted in them not always relating to the offered course material or finding course content irrelevant to real-life problems (Liu & Blanc, 1996; Wilson, 2002). They were also found to be overwhelmed by the cohort of men who seemingly "dream in code" (Margolis & Fisher, 2003). Interestingly, women tended to lay low, be unwilling to ask "*dumb*" questions, and or compete for resources at hand in their first CS classes, none of which were characteristics of male students in the same program (Staehr et al., 2000). However, it is important to say that no gender gaps were identified between the success of male and female students in more advanced CS classes (Vilner & Zur, 2006).

Self-Perceptions

Finally, self-perceptions, such as the amount of self-efficacy, or belief in one's abilities, were also found to influence women's retention in CS (Ashcraft et al., 2012; Fisher et al., 1997; Rubio et al., 2015; Singh et al., 2007; Wilson, 2002). In comparison to their male cohort, women often reported having lower programming abilities (Ashcraft et al., 2012; Beyer, 2014; Fisher et al., 1997; Rosson et al., 2011; Singh et al., 2007; Wilson, 2002) and lower self-efficacy (Beyer, 2014; Frieze & Quesenberry, 2015; Rosson et al.,

2011; Wilson, 2002). Frieze et al. (2012), for example, found that 54% of women in their study felt that others performed better than them. While such perceptions were well correlated with their actual grades, the same was not the case for their male peers who perceived themselves as performing better than reflected in their grades (Wilson, 2002). This suggests that even though female students reported a lower self-efficacy than their male peers, they were actually more realistic about their abilities. In addition, women were found to perceive themselves as slower learners (Margolis et al., 2000), and were more likely to rate themselves low on math ability, intellectual self-confidence and competitiveness (Lehman et al., 2016).

Studies focusing on individual factors provide valuable insights into some gender differences between male and female students in CS majors, such as the difference in prior experience, participation patterns and self-perceptions. However, such studies tend to portray women as deficient in something (Cohoon & Aspray, 2006). Such view of equality is simplistic as it fails to address social structures that may be causing the inequalities (Vitores & Gil-Juárez, 2016) and can further perpetuate stereotypes and marginalize women in CS (Frieze & Quesenberry, 2015). Instead, we need to understand individual differences among women (Trauth, 2011) and make sure we continue to hear their voices (Wasburn & Miller, 2006).

Interventions Addressing Individual Factors: CS Courses. Taking research on gender differences into consideration, many programs experimented with rethinking and redesigning their CS courses to create a more gender inclusive and less gender-biased environment. While some of these interventions focused on securing a positive first

experience in programming (e.g., Alvarado & Dodds, 2010; Beyer, 2014; Dekhane et al., 2017; Dekhane & Napier, 2017; Gokhale & Stier, 2004; Latulipe et al., 2018; Liu & Blanc, 1996), others focused on designing programming courses around female preferences, such as contextualized (Jessup & Sumner, 2005; Jessup et al., 2005; Rubio et al., 2015) or social aspects of programming (e.g., Cox & Fisher, 2008; Hanks et al., 2011; Sankar et al., 2015; Settle & Steinbach, 2016) that have been found to be important aspects for female engagement.

(Pre-)Introductory CS Courses. Positive experience in students' first CS classes was shown to predict greater intention to take CS courses in the future (Beyer, 2014). On the other hand, introductory courses which did not align with women's prior experience or intellectual preferences were found to be the main reason for them leaving the program (Roberts et al., 2012). For that reason, some interventions focused on securing a positive experience for women in their introductory CS courses. Some interventions worked on providing an inclusive environment by setting the tone, participation opportunities and gender-neutral examples (e.g., Gokhale & Stier, 2004). Others catered to women's intellectual preferences and prior experiences, by teaching preferred types of programming, providing CS terminology explanations more thoughtfully, and choosing course assignments that were relevant to the real world (e.g., Liu & Blanc, 1996; Rankin & Thomas, 2016). Latulipe et al. (2018), for example, found that flipped classroom format retained new freshman women better than the traditional classroom format. Some studies even worked on offering pre-introductory CS courses which aimed to make up for lack of prior experience, lack of background knowledge (e.g., Alvarado & Dodds, 2010;

Dekhane et al., 2017; Dekhane & Napier, 2017) and or teaching soft skills in addition to technical ones (e.g., Lewis et al., 2008). As an example, researchers at Georgia Gwinnett College organized a five-day summer programming boot camp for females enrolling into an IT major and minor (Dekhane et al., 2017; see Dekhane & Napier, 2017), consisting of intense Java programming sessions and professional development sessions based on pair programming and peer-led team learning. Females who attended the camp were found to both perform better and have a better retention rate in the program in comparison to the females who did not attend the camp (Dekhane & Napier, 2017). The impact, however, was found to be short-term (Dekhane et al., 2017).

Situated Programming. Contextualizing programming in real life situations where students could see direct implementation and use of programming (e.g., Gokhale & Stier, 2004) was another axis around which CS course interventions had been designed. A design-based course where students made computational products to address the needs of local community service organizations was one example of such a course (Jessup et al., 2005; e.g., Jessup & Sumner, 2005). A physical computing approach, where they could take computational concepts out of the screen and into the real world to program toys, robots and similar, was another popular intervention designed to retain female CS students (e.g., Rubio et al., 2015).

Collaborative Programming. Another strategy frequently used in designing CS courses has been to cater to women's social preferences, and allow women to work collaboratively, as it has been proven to increase retention (Krause et al., 2012). One format of collaborative courses has been to design it around pair programming, which

was found to benefit women, while it had no negative effects on the quality of their individual programming in more advanced courses (Hanks et al., 2011). Another format of collaborative courses, same-sex project groups in class, was found to give girls a sense of empowerment, fairness, and comfort, while the group itself motivated them to learn and contribute more without any sense of intimidation (Cox & Fisher, 2008). Settle and Steinbach (2016), for example, provided social support for men of color and women in CS by building a learning community, where students could enroll in a few simultaneous courses together, including CS1 and an introductory course to Python. The experience contributed to a higher retention rate (88%) for all the underrepresented students participating in the community (versus 50% rate for those who did not). The students participating in the learning community also reported feeling more supported, having a greater sense of belonging to a community of programmers, and had a better point average from those underrepresented students who did not participate in the community.

Institutional Factors

As a response to criticism of studies focusing on gender gaps, which some researchers believe can perpetuate stereotypes (e.g., Cohoon & Aspray, 2006; Fisher et al., 1997; Frieze & Quesenberry, 2015), another line of inquiry emerged in the investigation of retention of women in CS. These studies focused on examining different institutional factors that influence women's retention in CS. What is more, this second line of research highlights institutional factors as central to the attrition of women. As an example, one study found that while men changed their major due to external factors (e.g., they found a major they liked better), women's decisions to leave CS were usually

influenced by factors within the major, such as being treated differently than men in the same program (Bunderson & Christensen, 1995). The most influential institutional factors identified in literature were interactions with the faculty and/or peers, as well as the nature of the institutional culture and or classroom atmosphere, which will be discussed in this section.

Interactions with Faculty

Known to set school atmosphere both positively and negatively (Larsen & Stubbs, 2005), teachers can directly and/or indirectly influence the whole experience of women studying within the institution. According to Cohoon (2001, 2002a, 2002b) and Metcalf et al. (2018), lack of female role models, high faculty turnover, low teaching quality, poor mentoring, as well as lack of faculty belief into their own responsibility for student success were some of the issues in connection to faculty that were found to deter women from their CS major. In comparison to their male cohorts, women were much more likely to report negative experiences with or opinion about CS faculty (Barker et al., 2009; Denner et al., 2014), and yet they were much more likely to seek help from them, as well (Varma & Hahn, 2007). What is more, lack of faculty involvement was found to undermine departmental or university efforts to promote retention of women in CS majors (Varma & Hahn, 2007), while encouraging and engaged faculty were found to be one of the most influential factors on retention of women in CS (Cohoon, 2006).

Classroom Experience

Additional influencing factors were identified inside the CS classroom.

Bunderson and Christensen (1995), for example, found that both faculty and teaching assistants tended to discriminate against women inside the classroom, a phenomenon which ranged from simple marginalization to concrete examples of mocking and harassment. Some studies found that women felt left out if class material examples were not gender neutral (Benbow & Vivyan, 2016; Gokhale & Stier, 2004; Medel & Pournaghshband, 2017; Miliszewska et al., 2006), if male peers dominated class communication, if class climate was too competitive (Gokhale & Stier, 2004), and/or if faculty created a work climate in which prior knowledge was equated with being smart (Singh et al., 2007). Kapoor and Garden-McCune (2018), for instance, found that women who considered switching out of their CS major were not satisfied with their CS courses, the main reason being that they did not receive timely feedback and or they felt there was a gender bias in the classroom.

Institutional Culture

Several studies also found that institutional culture in the whole CS major and/or program was hard for some women to relate to. In a study by Bigger et al. (2008), women described the culture in their CS major as masculine, which was stated as one of the main reasons they left. In other studies, women mentioned feeling they needed to be intelligent, unathletic, geeky and socially detached if they wanted to integrate into CS (Bunderson & Christensen, 1995; Margolis & Fisher, 2003; Redmond et al., 2013). In addition, they perceived men who succeeded in the major as people who dreamt in code and had magnetic attraction to computers, none of which came naturally to them. Main and Schimpf (2017) in their review of literature found that some of the most frequently

identified factors influencing high attrition rates for females were prevailing stereotypes and male-dominance inside the major. According to Margolis et al. (2000), stereotypical perceptions of CS, which started as early as first semester, had the power to directly erode women's interest in CS. Considering that women exhibited fewer negative stereotypes than men, prior to enrollment (Beyer, 2014), these findings are alarming, as they suggest that the majority of women's stereotypical perceptions formed inside the institutions (Cheryan et al., 2015) and were perpetuated by the institutional culture.

Interactions with Peers

Finally, as far as peer interactions are concerned, these were found to be mostly dependent on the gender of the peer, with interactions with male cohort often having a negative effect, and female having a positive one. Research shows that peer interactions with male cohorts often included exposure to open doubt about the innate ability of women to succeed in CS (Bunderson & Christensen, 1995), various types of sexist behavior (Barker et al., 2009; Clegg & Trayhurn, 2000), preening (Benbow & Vivyan, 2016) and/or marginalization (Gokhale & Stier, 2004). In the last study, women reported often needing to prove themselves first prior to becoming part of the community. Several studies further showed that a mere accumulation of negative comments, teasing and belittling, or a simple cultivation of a sexist environment made women feel undervalued and unwelcome so much so that they lost interest in pursuing CS as a major (Cohoon, 2001; Gürer & Camp, 2002; Margolis et al., 2000). The mere act of being completely surrounded by men, as this is a male-dominant field, also created tensions for women, as they made collaboration or support outside classes difficult (Benbow & Vivyan, 2016).

Additionally, Kapoor and Gardner-McCune (2018) found that difficulties in dealing with "slackers" also made some women switch to a different major.

On a more positive note, several studies suggested that interactions with female peer-role models had a positive effect on retention (Biggers et al., 2008; Cohoon, 2002a, 2006; Cuny & Aspray, 2002; Frieze et al., 2012). These studies, with the exception of Cohoon (2006), were mostly using role models as a retention strategy rather than finding evidence of the effectiveness of peer role models on retention.

Findings about institutional factors emphasize the importance of inclusive institutional culture, which contributed to the design of many successful interventions, such as the program at Carnegie-Mellon (see Fisher et al., 1997; Frieze et al., 2006, 2012; Larsen & Stubbs, 2005; Margolis et al., 2000; Margolis & Fisher, 2003). This program managed to dramatically increase the number of women inside the major by introducing a number of institutional changes (Larsen & Stubbs, 2005). However, these studies, in addition to those focusing on gender differences, are more frequently focusing on factors detrimental to retention then they are on factors promoting retention. As a matter of fact, studies that identify factors which influence women to remain in the program (e.g., DuBow et al., 2017; Rosson et al., 2011; Wilson, 2002) are extremely rare. To be able to design more efficient retention interventions for women in CS, it is crucial that we gain full understanding of women's experience throughout the program. This includes understanding participation pathways of women throughout the program, as well as practices and other factors which strengthen their commitment to full participation in this community.

Interventions Addressing Institutional Factors: CS Programs. Though many institutions introduce interventions designed around institutional factors with a goal of retaining more women in their CS programs, not all of them are successful. According to research, what makes a program successful is their ability to "consciously and strategically position [the program] within the structure of their institution and work toward systemic transformation and change" (Fox et al., 2009, p. 348). According to Fox et al. (2011), the most common problem of unsuccessful programs is their tendency to define the root of female underrepresentation in CS as structural (or institutional), but then design interventions which target individual female attributes, an approach which basically suggests that women should "toughen up and adjust" (Margolis & Fisher, 2003, p. 91). Though there is not much agreement in literature on what makes a successful CS program, most authors agree that the most important goal in creating these types of interventions should be to create woman-friendly environments, inclusive of gender diversity, and to promote good student relations (Cuny & Aspray, 2002) and multiple standards of excellence (Margolis & Fisher, 2003). According to Frieze et al. (2012), any departmental culture is malleable and could potentially be shaped (and reshaped) by its members to change the attitudes of their students, considering that attitudes are not gender specific, regardless of how they may appear.

The Carnegie-Mellon Case. One of the success stories and perhaps the most well-studied CS programs, which successfully reshaped its culture and increased both graduation percentage for women (40%) and retention overall to 89% (Frieze & Quesenberry, 2015), is the Carnegie-Mellon program intervention (see Fisher et al., 1997;

Frieze et al., 2012, 2006; Larsen & Stubbs, 2005; Margolis et al., 2000; Margolis & Fisher, 2003). This university introduced a new CS program in 1999, where they deemphasized the importance of prior experience for admission, and emphasized high math and science achievement, as well as more diverse interests (Frieze & Quesenberry, 2015). Such shift in admission criteria resulted in a more diverse student body which led to a more balanced environment in terms of gender, personalities and professional help, all of which resulted in better participation, contribution and success for women (Frieze et al., 2012). In the beginning, progress in retention rates was slow (Fisher et al., 1997; Margolis et al., 2000). After a few years, however, the culture changed. Geek mythology was challenged by presenting a cohort of multidimensional, social and well-rounded students, both male and female (Frieze et al., 2012). Consequently, women started perceiving the new departmental culture as enjoyable due to the presence of fun activities, diverse people and available research (Larsen & Stubbs, 2005). Frieze and Quesenberry (2015) also found that students enrolled in the reformed program had overwhelmingly positive attitudes towards programming, felt comfortable inside the CS community of their program and had a good life-work balance in general.

Other Successful Programs. A few other programs also recorded positive change in their enrollment and retention rates in CS majors through a variety of different strategies. For instance, a combination of peer mentoring, peer tutoring and supplemental instruction was offered to first year female students at La Trobe University in Australia, all of which were found to increase retention (Staehr et al., 2000). Prevention of marginalization and discrimination of female students was also addressed as crucial in

some interventions (e.g., Treu & Skinner, 2002). Settle and Steinbach (2016) built a linked-course learning community for minority men and women in their CS programs, which was found to both support retention of these groups and significantly reduce students' sense of isolation. Harvey Mudd College, another university that had success in increasing retention of women in CS, implemented three innovative practices which raised their graduation of women to 37-50% depending on the year (Klawe, 2013): (1) they made two major changes to their introductory CS courses (students placement in different sections was based on prior experience and instructors were asked to actively discourage the most experienced students from showing off); (2) they created access for female students to attend the Grace Hopper Celebration of Women in Computing conference that is geared towards women in computing; and (3) they provided summer research opportunities for undergraduate women.

External Factors

Considering that educational institutions do not exist in a vacuum, retention of women in their CS major was also found to be influenced by factors external to the institution, such as their families, friends, coworkers and other communities that they belong to, as well as the cultural norms and values that those communities hold. Lack of external support, for instance, was found to be deterring to the persistence (Denner et al., 2014; DuBow et al., 2017; Miliszewska et al., 2006; Roberts et al., 2012; Rosson et al., 2011), while certain cultural norms and values, such as the social desirability of CS degree for a woman, influenced certain women to persist (Eidelman & Hazzan, 2005; Fokum et al., 2016; Galpin, 2002; Ojokoh et al., 2014; Schinzel, 1999; Varma, 2010;

Varma & Kapur, 2015). In addition, work-related experiences were also found to have an effect on retention of women in CS majors (Beyer, 2014; Beyer et al., 2005; Kapoor & Gardner-McCune, 2018). Research on the influence of external factors on the retention of women in CS, however, has not been extensively explored. An overview of studies that have been conducted is provided in this section.

Work-Life Balance

One of the deciding external factors on retention of women in CS were concerns women had about future family-work balance (Beyer, 2014; Beyer et al., 2005). Women were found to be more family-oriented, in comparison to their male peers, which was found to be a significant predictor of attrition (Beyer, 2014).

Other Work-Related Factors

Kapoor and Gardner-McCune (2018) also found that women who had good leadership experience at work were more likely to consider dropping out of the major and changing to a major in management. The same authors found that internship experiences could either have positive influence in terms of reinforcing women's persistence in the major, or negative influence by making them realize that they did not want to do that type of a job for the rest of their lives. Work communities, however, are not frequently researched in relation to female retention in CS.

External Peer Interactions

Ashcraft et al. (2012) emphasized the importance of communities for women to get access to computing, professional role models and other resources. External peer

encouragement, in particular, was found to be crucial in choosing CS as a major (Denner et al., 2014; Singh et al., 2007) and one of the two critical factors in constructing women's ongoing experiences in their CS majors (Rosson et al., 2011). That is, lack of support from women's peer networks outside the university major was found to be deterring to retention, while the opposite was found to increase their likelihood of persisting. In addition, Roberts et al. (2012) found that an inability to find peer support was one of the main reason women left the program. DuBow et al. (2017), on the other hand, found that those women who persisted in CS had enough community support, respect and encouragement from a variety of people along the way.

Family Interactions

Another type of support which was found to be crucial for choosing CS as a major is family support (Ashcraft et al., 2012; Singh et al., 2007). For example, Frieze and Quesenberry (2015) found that family was the primary force of exposure to CS, while family members often served as CS role models for those women who chose to pursue CS as their major. In this study, they also found that fathers were often the major influence on their daughters in terms of entering CS. Women who were more persistent in the program reported receiving more family encouragement (Lin, 2016), and having mothers with a Bachelor's degree (Denner et al., 2014; DuBow et al., 2017), which can be construed as a different kind of role modelling. Overall, however, there was evidence to show that women received less family encouragement than men to stay in CS (Miliszewska et al., 2006), and were exposed to gender biases even at home (Gürer & Camp, 2002).

Cultural Norms and Values

Several studies, most of which had been conducted in international contexts, bring out the importance of cultural norms and values to the retention of women in CS majors. As an example, two studies conducted in India (Varma, 2010; Varma & Kapur, 2015) describe the positive motivational influence patrifocal community values had on high retention rates of women in CS in India, where 55% of CS degrees in India in 2003 were earned by women (Government of India statistics, as cited in Varma, 2010). Some of these values include the fact that a CS degree is seen as one of the most desirable degrees for women with a potential to provide them with societal acceptance, good marriage prospects, good job opportunities, and independence from certain social obligations (Varma & Kapur, 2015). Similar studies found that high retention rates were influenced by the high social status CS had for women in Nigeria (Ojokoh et al., 2014), or an opportunity some international women in CS majors in the US had to become the breadwinners for their families at home (Margolis & Fisher, 2003). Finally, a study done in Israel found noticeable participation differences between Arab and Israeli students with Arab women being more likely to persists due to larger extent of encouragement they received from various their community (Eidelman & Hazzan, 2005).

Despite a modest number of studies focusing on external factors, their existence created awareness about the fact that the problem of underrepresentation of women is not necessarily universal, but may in fact be cultural, which hints at the existence of some unearthed elements influencing retention. However, the role of culture in underrepresentation of women in CS has been under-researched and non-western realities

are almost invisible in research (Vitores & Gil-Juárez, 2016). This calls for a more holistic approach to researching retention of women in CS, one in which interpretation of a person's social environment is included in the overall understanding of what has been observed (Patton, 2002). According to Patton, such approach demands a set of diverse methods which allow gathering data on multiple aspects of the setting under study. So far, studies identified in my literature review were mainly using either survey or interview data, while observations, a method frequently used in holistic studies, were only used once (Pantic & Clarke-Midura, 2019). By using a more holistic approach to research, one which takes the complexity of the phenomenon into consideration, greater attention can be given to nuances and interdependencies (Patton, 2002). By surveying literature, we also found a dearth of empirical studies (n=7) that used an exclusively female sample (Pantic & Clarke-Midura, 2019), while the rest used a mixed-gender sample with women often being dramatically outnumbered. Such an approach to research about women in CS can be both misleading and/or incomplete. For that reason, it is of paramount importance to focus on the experience of women alone, despite the limited number of women enrolled in CS majors (Wilson, 2002).

Retention of Women Across the Globe

Not all countries of the world, however, struggle with retention of women in CS education (Galpin, 2002). In Europe, for example, the problem seems to be reserved for the more developed countries, with Switzerland reporting the lowest number of female graduates (19%) (Mejer et al., 2011). Other countries that have recorded low graduation rates for women in CS are Denmark and Germany (United Nations Educational,

Scientific and Cultural Organization [UNESCO], 2015), Norway (Pappas, Aalberg, et al., 2016; Pappas, Giannakos, & Jaccheri, 2016), as well as some non-European countries, such as Japan (Mejer et al., 2011), Canada (Hango, 2013), Australia (Craig, 2014), and New Zealand (Hunter & Boersen, 2016).

On the other hand, Romanic and Slavic countries in Europe, as well as Greece and Turkey have higher participation of women in CS (Schinzel, 1999). Countries such as India and Malaysia also have good representation of women in CS (UNESCO, 2015). A study done in the Caribbean, for example, which included participants from Jamaica, Barbados and Trinidad, found that female CS students had a better GPA in computing classes and a better retention rate in the first three years of college than their male peers (Fokum et al., 2016). In their study of Carnegie Mellon University, Frieze and Quesenberry (2015) found that some international women from countries such as Morocco, Romania and Iran were surprised by the existence of the gender gap in the US, as it never occurred to them growing up that they could not study and or be successful in this field. Some researchers even found variations inside the same country between different ethnic groups, such as the differences between Arab and Jewish women in Israeli high schools (Eidelman & Hazzan, 2005). Naturally, differences exist between individual women, as well, due to the amount of gender bias they encounter, differential experience, and/or their individual consciousness of the bias, differential response, or the sense of personal agency (Trauth, 2011).

There are no clear patterns to explain the existence and/or the absence of the gender gap in CS education in different countries (Galpin, 2002) and or cultures. Some

researchers consider that it is a matter of technological development, while others believe that it is a matter of a variety of factors, such as the hindrance of the gendered job market, or a social desire to uphold gender hierarchies in certain countries (e.g., Schinzel, 1999). For those reasons, in this dissertation I explore how retention of women in CS majors is affected by their participation in cultural practices of the social community of their CS major.

Theoretical Framework

This dissertation focuses on understanding the types of social engagements and other practices within and or around a CS major that provide a context for ongoing participation (i.e., retention) and learning of women in a CS major. To that end, I use the lens of LPP within CoP (Lave, 1996, 2009; Lave & Wenger, 1991, 2011; Smith, 2009; Wenger, 1998b, 1998a, 2000, 2009; Wenger et al., 2002; Wenger-Trayner, 2015) to understand different types of social engagements and practices within or around their CS major that provide appropriate context for learning and retention for the women in my sample.

LPP within CoPs views learning as an increase in social participation in CoPs (Wenger, 2009). As such, learning is interdependent with the activities, practices and social interactions CoP members are engaged in (Lave, 2009; Lave & Wenger, 1991) and it implies both skill acquisition and the process of becoming a different person in relation to new possibilities one is exposed to as they engage in new activities and interactions (Lave & Wenger, 1991; Lemke, 1997; Wenger, 2009, 2010). In the context of a CS

majors, learning would not only imply the process of acquiring programming skills, but also the process of becoming a computer scientist. Additionally, learning is always bidirectional and it benefits both the newcomers and the people they interact with (Dawson, 2013; Laxton & Applebee, 2010).

Within this framework, learning consists of two phases: (1) the way-in phase, which is the period of observation and creation of first approximations of practice, and (2) the practice phase, where newcomers participate in partial or full production of CoP artefacts (Brown et al., 1989; Lave & Wenger, 1991), which in the context of this study would be software. We can be engaged in the practice directly by the practice itself, and/or we can be engaged indirectly by producing the physical and conceptual artifacts that reflect our shared experience inside the practice (reification; Wenger, 1998b, 2010). These two distinct lines of memory need to be in interplay to create a social history of learning which eventually gives rise to a CoP (Wenger, 2010).

A product of learning, according to this theory, is our knowledgeability, which in the context of this study is knowledgeability about CS. Knowledgeability is much more than a display of socially constructed and negotiated competence (Wenger, 2000) as it also consists of our ongoing experience. The act of knowing is both ever-changing (Lave, 2009) and dynamic (Wenger, 1998a). Our participation in a CoP shapes not only what we do, but also who we are and how we interpret the world around us (Wenger, 2009). To remain knowledgeable, we need to stay in touch with the innovations in the field, but at the same time, our knowledgeability is influenced by our participation in other activities not always related to the one and same CoP (Wenger, 1998a). Two central tenets of this

theoretical framework that influence the dynamic of knowing are:

1. situated learning (the knowledge we obtain in and apply to everyday experience) and
2. reflective practice (i.e., our critical examination of current and past engagement in order to improve our future practices) (Buysse et al., 2003).

To develop knowledgeability, therefore, we need to gather experience and engage in critical examination of our practices in relation to how efficient they are in enhancing our knowledgeability. Reflective practices, therefore, could be crucial in shaping the ongoing participation of women in CS majors depending on how useful the practices they are engaged in are perceived to be for the development of their competency.

LPP within CoPs provides a useful platform to discuss retention of women in CS majors because retention can be construed as ongoing and increasing social participation inside a CoP of their CS major, while learning implies both skill development and the act of becoming a computer scientist. Thompson (2005) calls the process of increased participation, identification, learning and motivation inside CoPs a "virtuous circle" (p.152). Virtuous circles allow members of the community to remain motivated in a practice through active participation. It is the dynamic of virtuous cycles that allows CoP members to persist in their participation. According to Thompson (2005), the more engaged we are in a CoP, the more we learn and identify with that practice, which in turn keeps us motivated to remain engaged in that same practice (hence, a "circle"). Along those lines, Guldberd and Mackness (2009) suggest researching enablers or factors that enable participation, which is the focus of my RQ1. The following sections describe the most important concepts inside this theoretical framework which help explain women's ongoing participation (i.e., retention) inside the CoP of the male-dominant CS major, as

well as how those concepts are shaped by RQ2 and RQ3.

Communities of Practice

The CoP concept has its roots in anthropology and social learning theory (Wenger, 2010), but it has also been influenced by other theoretical bodies, such as theories of learning, social constitution, identity, practice and situatedness (Thompson, 2005). To date, it has influenced both theory and practice in many fields, such as education, healthcare, business management, government and the civil sector (Wenger, 2010).

Definition and Key Features

CoP is a construct that describes a particular model of learning (Hoadley, 2012), where a group of people with mutual concerns, problems or passions about a topic "deepen their knowledge and expertise in [an] area [of mutual interest] by interacting on an ongoing basis" (Wenger et al., 2002, p. 4). CoPs are social configurations formed by "people who engage in the process of collective learning within a shared domain of" interest (Wenger-Trayner, 2015, p. 1), such as students, professors and other members of CS majors do inside that major. This process implies working together, sharing information and helping each other (Cassidy & Gurm, 2016). It is a set of interrelations between people, activities and the world over time and in relation to other seemingly unrelated and/or overlapping CoPs (Lave & Wenger, 1991).

Inside CoPs, knowledge does not reside in one master (e.g., a CS professor), but in the overall organization of the CoP (Lave & Wenger, 1991). For that reason, individual

members have their own unique learning curriculums, directed by their own reflective practices, which evolve from unique engagement in the CoP and the interactions each individual has with peers, exemplars, learning resources and other situated opportunities (Lave & Wenger, 1991). As an example, in a CS major, each woman would have their own unique learning curriculum led by her unique engagement and critical examination of her own practices.

CoPs are defined by three parameters: one structural (shared repertoire) and two epistemic (mutual engagement and joint enterprise) (Thompson, 2005). In other words, for each CoP, there are internally negotiated rules on what the CoP is about (aka joint enterprise or a shared domain of interest), how it functions (aka mutual engagement or a collective commitment to the community) and what capability it produces (a.k.a. shared repertoire; Thompson, 2005; Wenger, 1998a, 1998b). A shared repertoire includes both resources and ideas, such as routines, sensibilities, artifacts, vocabulary, and or style (Smith, 2009). In a CS major, for example, members of each CS department collectively engage in that major, but they also collectively negotiate their unique mission, courses, prerequisites, and tracks, as well as what it means to be a competent computer scientist.

These three parameters mentioned above were revised by Wenger, McDermott and Snyder (2002) to include domain, community and practice. They define domain as the minimal competence that creates common ground and differentiates members from non-members, community as the social structure that facilitates learning, and practice as a set of shared repertoires. Table 1 displays other key characteristics of CoPs compiled from Wenger (1998b) by Thompson (2005) and Roberts (2006).

Table 1

Key Characteristics of Communities of Practice

No.	CoP characteristic
1.	Sustained mutual relationship – harmonious or conflictual
2.	Shared ways of engaging in doing things together
3.	The rapid flow of information and propagation of innovation
4.	Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process
5.	Very quick setup of a problem to be discussed
6.	Substantial overlap in participants' descriptions of who belongs
7.	Knowing what others know, what they can do, and how they can contribute to an enterprise
8.	Mutually defining identities
9.	The ability to assess the appropriateness of actions and products
10.	Specific tools, representations and other artifacts
11.	Local lore, shared stories, inside jokes, knowing laughter
12.	Jargon and shortcuts to communication as well as the ease of producing new ones
13.	Certain styles recognized as displaying membership
14.	A shared discourse reflecting a certain perspective on the world

CoPs structure participation around four things: (1) opportunities to observe and participate, (2) direct in-person interaction, (3) narratives that members listen to and elaborate on, and (4) routines and roles that they can practice and play with (Rogoff, 2003). To participate in a CoP, such as a CS major, therefore, one needs access to the opportunities to observe more seasoned members involved in meaningful practice, interact with other members, and be exposed to insightful narratives, while at the same time being able to play with different routines and roles of the field. Even though CoPs are fundamentally self-organizing (Wenger, 1998a, 1998b), that is, members always self-select to participate in them (Wenger & Snyder, 2000), what holds CoPs together is

members' passion, commitment (Wenger, 2000) and a sense of connectedness (Hemmasi & Csanda, 2009). If passion, commitment and connectedness are lacking, members are likely not to persist with their engagement in that CoP. Additionally, CoPs fail if practice is intangible, competences are rigid, or there is lack of identification with it, lack of core groups and/or there is a low level of one-on-one interactions between members (Probst & Borzillo, 2008). This is aligned with research on factors that influence women to leave CS majors, which was described earlier in this chapter.

The purpose of CoPs is to support knowledge sharing, artefact sharing (Evans & Powell, 2007), and the creation and accumulation of knowledge (Wenger, 1998a). They are ideal for initiating newcomers, stewarding competencies and providing homes for identities, as they are organized around common interests. They also provide us with means for innovation and creative problem solving (Li et al., 2009). CoPs can drive strategy, generate new businesses, solve problems, promote the spread of best practices, develop people's professional skills and help organizations recruit and retain talent (Wenger & Snyder, 2000). If we construe CS majors as CoPs where students develop their skills in CS as they are initiated into the CS community through classes and social interactions, studying the process of women's ongoing participation has the potential to reveal the mechanisms which support it. As an example, research shows that typically, it is the core members or full participants who energize the community with their passion and provide intellectual and social leadership (Wenger & Snyder, 2000), but that the organization itself can also do a lot to design and/or support the CoP (e.g., Nett, 2008; Probst & Borzillo, 2008; Wenger, 2010; Wenger et al., 2002; Wenger & Snyder, 2000).

Table 2 presents different stages that CoPs go through as they develop. These stages depend on members' level of interaction inside the community (Wenger, 1998a). Based on this Table, upperclassmen women in a CS major represent members that actively engage in a CS practice, with high level of engagement, while CS major with all its members represents a CoP in an active stage of development.

Table 2

Stage of CoP Development (adapted from Wenger, 1998a)

Stages of development	Description of the stage	Level of engagement	Typical activities
Potential	People face similar situations without the benefit of a shared practice	Low, moving upward	Finding each other, discovering commonalities
Coalescing	Members come together and recognize their potential	Medium, moving upward	Exploring connectedness, defining joint enterprise, negotiating community
Active	Members engage in developing a practice	High	Engaging in joint activities, creating artifacts, adapting to changing circumstances, renewing interest, commitment and relationships
Dispersed	Members no longer engage very intensely, but the community is still alive ad a force and a center of knowledge	Medium, moving downward	Staying in touch, communicating, holding reunions, calling for advice
Memorable	The community is no longer central, but people still remember it as a significant part of their identity	Low, moving downward	Telling stories, preserving artifacts, collecting memorabilia

It is important to note that individual CoPs can sometimes have a complex structure and consist of different fractal or mosaic layers of embedded subcommunities (Lemke, 1997). Fractal layers develop when CoPs are overextended and they have to split into subgroups to increase their efficiency (Wenger, 2000). Inside a CS major, for

example, fractal structure is reflected in the existence of different clubs (e.g., ACM-W), tutoring centers and other more informal CoPs (e.g., community of gamers) inside the overall CS major CoP.

Multimembership

Knowledgeability, however, does not always develop inside one CoP, such as a major. According to Lemke (1997), to develop true mastery of practice, it is often necessary to participate across different CoPs. A typical example is the link between schools and work. In the context of this study, I posit that to develop true expertise, women in a CS major need to both actively engage in their CS major and have a job inside the industry where they can learn next to more seasoned members of the community, test the competencies they developed and get acknowledged as valuable members of the community.

We all belong to multiple CoPs (Wenger, 1998a, 2009), which to some extent contribute to our diverse competencies. Such multimembership is an intersection of all the relationships that our experience of being a human consists of (Wenger, 2000) and is therefore, a norm (Fincher & Tenenberg, 2006). In some communities, we are core members, in others, we are more at the periphery (Wenger, 1998a). On the other hand, some communities enable us to test the competencies we developed across different CoPs (Dawson, 2013).

Lemke (1997) calls these networks of linked or interdependent CoPs, an ecosocial system. Wenger (2000, 2010) calls them a social learning system, which he defines as a constellation of interrelated CoPs. Boundaries between different CoPs are not fixed, but

flexible and continuously shifting (Roberts, 2006; Wenger, 2000). As a matter of fact, the learning potential of a particular CoP is largest when the core and boundaries of it are active in a complimentary way, according to Wenger (1998a). Connections between different CoPs are usually initiated by people Wenger (1998b) refers to as "brokers," who help people enter or bridge different CoPs. For example, in a study exploring different models of parent-teacher participation in special education, mothers' brokering role was found to be crucial for bridging different CoPs included in their child's special education experience (Laluvein, 2010).

In my research, I argue that the CS major can be construed as a CoP. This CoP consists of practitioners (Cassidy & Gurm, 2016) who have similar skills, practices and language for engaging in the same practice (Fincher & Tenenberg, 2006). The practitioners consist of professors, teaching assistants, peers, tutors, staff members, club organizers and similar members at different levels of expertise, all of whom are collectively engaged in building and or developing CS competencies. They share a repertoire of resources important for CS education and expertise. Students are socialized during their work in class (Ferreira, 2010), work on homework assignments, study groups, tutoring labs and so on. Education inside a CS major focuses on developing students' tacit (theoretical) skills in combination with some explicit or practical skills (Poggenpohl, 2008). These skills are often developed in a controlled classroom environment and detached from real life situations. Therefore, like in any other major, it is not uncommon for students to move between different CoPs (e.g., school and work) with a goal of fully developing their expertise (Lemke, 1997). According to Fincher and

Tenenberg (2006), external CoPs are valid because they validate the knowledge and practices we gain in current CoPs, which additionally strengthens our commitment to our own education. I posit that while some external CoPs contribute to women's competency development, others are crucial for their persistence in the major. Therefore, I believe it is important to investigate women's retention in CS in association with all the communities and CoPs that they actively participate in, which is the rationale behind my RQ2.

Legitimate Peripheral Participation

To develop knowledgeability, newcomers have to be actively engaged in a CoP (Wenger, 1998b). However, only engagement in meaningful learning activities leads to competency development. For that to happen, newcomers need to approach their learning in two ways. First, they need to have an active role in their learning (Rogoff, 1995) and take full responsibility for it (Buysse et al., 2003; Rogoff, 1993), as one's position in a CoP depends on their own level of participation (Tomaszewski, 2004). Second, they need to be given access to the right learning opportunities by the more experienced community members (Wenger, 1998b). That said, people rarely enter new CoPs as real novices to the practice (Dawson, 2013). It is more common for newcomers to have some level of diverse experience and expertise. For example, students enroll into a CS major with different levels of prior experience with programming and computing. Some of them may be true novices, but most of which will have some level of basic or more advance experience. Research shows, however, that the majority of women enter CS with very limited programming experience (e.g., Liu & Blanc, 1996; Ragsdale, 2013; Staehr et al., 2000).

The "process by which newcomers become involved" in CoPs (Wenger, 1998b, p. 100) has been defined as *LPP* (Lave & Wenger, 1991). LPP concept has been used to describe newcomers' engagement with the CoP practices (Toohey, 1998). It involves taking up practices within a CoP gradually, starting with tangential and moving towards more central ones (Hoadley, 2012). It refers to both the development of knowledgeably skilled identities and to the reproduction of the CoP itself, while it simultaneously provides ground for self-evaluation of the members (Lave & Wenger, 1991). Members know if and when they should join the CoP, if they have something to offer and/or take away, as well as whether that CoP aligns with their identities (Wenger & Snyder, 2000). The process of LPP, therefore, can cause identification or dis-identification with a particular CoP, depending on the experience members have with it (Wenger, 2010). As an example, disidentification can happen when CoP members do not see participation in a CoP as meaningful to their daily work (Probst & Borzillo, 2008). With that in mind, I posit that women who persist in their CS major believe CS major aligns with their identities and or were exposed to positive experiences inside the major, all of which contributed to their retention.

LPP process itself, however, is by no means a linear acquisition of skills. Instead, learning happens within two modified forms of participation, *peripherality* and *legitimacy* (Wenger, 1998b). Both of these concepts will be described and defined below.

Peripherality

Peripherality is a modified form of participation where the act of learning happens in environments of lessened pressure and risk with special explanations and supervision,

as a form of "apprenticeship" (Lave & Wenger, 1991). This is not to imply that the periphery is a single designated place within the CoP. Rather, it is an environment within which newcomers are given access to the practices and the repertoire of a particular CoP so they can learn through mutual engagement with others (Lave & Wenger, 1991). During this period, newcomers make tentative contributions to the CoP and learn how the CoP works (Olson, 2015). For example, women participate in their CS majors as students working on tasks that, though graded, do not pose a threat for a company or a product. They attend lectures where they have access to explanations and are supervised by professors and teaching assistants as they develop their competence in the subject matter. They mutually engage in these tasks with other peers through study groups, peer interactions and group projects.

Increasing participation, however, does not always lead to learning (Lemke, 1997). Key to LPP is gaining access to the full range of activities of the profession and/or full access to possibilities for learning that are needed to master the trade (Lave & Wenger, 1991). Peripherality, therefore, can be both empowering and/or disempowering, depending on whether one has access to the right resources and/or is kept from participating in the community (Lave & Wenger, 1991). I posit that women's retention in CS majors is influenced directly by the amount of access they get to the full range of meaningful learning activities and authentic practices.

Another crucial source of increasing participation is transparency. Transparency exists when participating, sociopolitical organization of the practice, its content and the significance of individual artifacts are visible and obvious to all members (Lave &

Wenger, 1991). Some of these include the language of the practice and the availability of masters (i.e., exemplars) who do not necessarily teach but embody practice at its fullest (Lave & Wenger, 1991). Apart from the masters, peers with different knowledge, experience and expertise have also been found to be valuable resources for learning and support (Hodgkinson-Williams et al., 2008; Lave & Wenger, 1991; Rogoff, 1993). In a CS major, transparency could be reflected in practices exhibited by older more seasoned peers and professors, as well as how classes are designed to make CS practice transparent. I argue that women who succeed in CS are very likely to access transparency through multimembership in different complimentary CoPs, such as a combination of school and work.

Sequestration or the act of limiting and or giving selective access to the practices of the community prevents newcomers from participation and disconnects them from the practice (Lave & Wenger, 1991). As a result, they never achieve full participation, or have an identical position and or trajectory of participation within the CoP in comparison to full members (Wenger, 1998b). Those members remain on the periphery or are positioned marginally to the community despite their active attempts to learn and participate (Wenger, 1998b). Marginalization of women in CS majors was identified as one of the reasons for the attrition of women in CS majors (e.g., Bunderson & Christensen, 1995; Gokhale & Stier, 2004).

One of the highly efficient ways of transmitting knowledge in a CoP is through language, which is why learning to talk like full/ core members of the community is key to LPP (Lave & Wenger, 1991; Smith, 2009). Stories about problematic and difficult

cases, the so-called “war stories” are also important in displaying membership, but they also serve as a good diagnosis tool in accessing the importance of one’s participation (Lave & Wenger, 1991). In their effort with primary teachers in the UK to develop research projects around LGBT equality, DePalma and Teague (2008) found that lack of CoP-specific language can exclude and belittle novice CoP members, as it prevents them from conversing meaningfully with the more experienced members of the community.

Legitimacy

Legitimacy, which is more important to confer than teaching, is the act of acknowledging newcomers as competent members, regardless of how many mistakes or violations they make (Wenger, 1998b). As an example, Boylan (2003) found that teachers can grant legitimacy to learners simply by noticing and checking in with them from time to time. When acknowledged and valued, learners can develop a sense of belonging to the community even though they may not be fully participating. For women in CS, this can reflect in their relationship with their professors, but also in their relationship with their peers and co-workers. As this is a male-dominant environment, being perceived as competent by the male peers can be crucial to their retention.

Legitimacy also refers to the authenticity of practice newcomers are exposed to (Lave & Wenger, 1991), or the level of alignment between what they are learning and the practices that are applicable and useful in the CoP of their choosing (Guzdial & Tew, 2006). In a CS major, authenticity of practice would reflect in the amount of relevant and useful courses that women can take, including courses which teach them how to persist. At the same time, I argue that women in CS major can receive legitimacy at work by

being seen as valuable members of the CoP and being exposed to authentic practices and learning opportunities.

When granted, legitimacy empowers learning. When denied, it results in neglect and exclusion (Wenger, 1998b). A study on teacher-parent participation patterns in relation to special education found legitimacy to be bidirectional, as both parents and teachers had to prove themselves in order to be accepted into a mutual CoP organized around children's special education (Laluvein, 2010).

Trajectories

Trajectories or journeys we embark on, during our enculturation into a CoP, are defined as the extent to which earlier events create the conditions for and/or shape our participation in both the present and the future (Lemke, 1997). Additionally, trajectories can influence the formation of our identities and are part of our identities (Wenger, 1998b, 2010). To get someone on a trajectory of participation that they can identify with, you have to provide them with access to resources that enhance their participation, engage them in innovative ways and involve them in discussions and reflections that are important for that CoP (Wenger, 2009). Trajectory of participation in one CoP can influence our level of participation across other CoPs (Tomaszewski, 2004). They represent our personal histories in the context of our active participation (Li et al., 2009). They lead us into memberships in different CoPs through networks of activities, interactions and practices that give us all the necessary tools to both understand core participation in a CoP and fully participate in it (Lemke, 1997). While there is average resemblance between trajectories of people with similar dispositions (e.g., women in

general or women in CS majors), different people will always create rare and unique connections depending on their unique engagements with different CoPs (Lemke, 1997). As an example, upon inspecting how health professionals become engaged in their CoP, Dawson (2013) found that such trajectories differ immensely from one person to another. What is more, some experiences along those pathways bring people forward and others provide setbacks for them (Richards, 2009). In this dissertation, I argue that understanding individual journeys of participation of women who succeed in CS majors is important as it provides insights into potential resemblances between different experiences as well as which aspects of those journeys could potentially bring other women on the same track forward. Women who persist in CS serve as role models (i.e., exemplars) to any female newcomers inside the CS major. Their journeys, therefore, are important because they can influence the journey and learning of other women in the major. I argue that in order to understand retention of women in CS, it is important to explore different journeys women who persist in this major embark on through their CS education. To reveal and offer some model journeys to women in CS, RQ3 specifically focuses on investigating and describing retention pathways of five women participating in this study.

As I will show in this dissertation, the process by which women get involved in the CoP of their CS major can, therefore, be construed as LPP, with different women having different participation journeys. To understand retention of women in CS, we would need to examine these journeys of ongoing participation. Do the above described conditions for efficient LPP stand for women learning inside CS majors? What does the

process by which they achieved ongoing participation look like? Were they awarded legitimacy and by whom? Which stories, interactions and activities enabled their participation along the way? Women's participation pathways in male-dominant CoPs are of outmost importance to gender equity in those fields (Ferreira, 2010). Thus, we need to carefully consider them (Lemke, 1997) when investigating female enculturation in this male-dominant educational experience, as such inquiry have the potential to expand our understanding of female exemplars in CS majors, which is the rationale for my RQ3. In this dissertation, I refer to the journeys of ongoing participation of women in CS as *pathways* to distinguish from Wenger's (1998b) definition which focuses on identity formation.

Research on LPP within CoPs

A perspective of learning as LPP within CoPs has been employed by a variety of studies (e.g., Ben-Ari, 2004; Boylan, 2003; Ceglie, 2009; Cowan, 2012; Cuenca, 2011; Dawson, 2013; DePalma & Teague, 2008; Griffin et al., 2005; Guldberd & Mackness, 2009; Guzdial & Tew, 2006; Hasrati, 2005; Kinloch et al., 2015; Laluvein, 2010; Lee & Roth, 2003; Nett, 2008; Ngulube & Mngadi, 2009; O'Donnell & Tobbell, 2007; Pacheco, 2018; Paechter, 2003; Probst & Borzillo, 2008; Richard, 2011; Rogoff, 1993; Spouse, 1998; Thompson, 2005; Tomaszewski, 2004; Toohey, 1998). It has also directly informed some initiatives in STEM education (e.g., Cowan, 2012; Fincher & Tenenberg, 2006; Newswander & Borrego, 2009) and CS education (e.g., Ben-Ari, 2004; Guzdial & Tew, 2006). Different constructs of this theory have been used to explore how people become part of different science-based CoPs (e.g., Aschbacher et al., 2010; Brickhouse et

al., 2000; Brickhouse & Potter, 2001; Hasrati, 2005; Lee & Roth, 2003; Newswander & Borrego, 2009; Tan et al., 2013) or how they develop their disciplinary identities (e.g., Bell et al., 2017; Cuenca, 2011; Hasrati, 2005; Hemmasi & Csanda, 2009; Pacheco, 2018; Pinkard et al., 2017; Richard, 2011; Spouse, 1998). Some research even advocates for the use of LPP in CoPs in CS education (see Ben-Ari, 2004; Guzdial & Tew, 2006), but, to my knowledge, no research study examined retention of women in their CS major using this theoretical perspective.

Findings from studies that investigate CoPs in education hint at a variety of ways in which transformative influences can be manifested in the process of LPP. Goldschmidt et al. (2016) found that accountability to particular groups of co-learners with which one could exchange resources and support was particularly important for a true learning experience of a group of faculty members. Others found that collaboration combined with an opportunity to observe and participate next to more seasoned members of the community led to a more developed sense of belonging to the community in question and a bigger motivation to learn further (Stewart et al., 2016). In addition, CoPs were found to afford their members with exposure to different perspectives and an opportunity to experience knowledge translation and transfer (Miller-Young, 2016; Rawle et al., 2016). Exposure to the right resources can also be transformative, such as relevant disciplinary language and methods (Lee & Roth, 2003; Vandermaas-Peeler, 2016) or passing of important networking opportunities, reading material and other artifacts (Strean, 2016). In their investigation of a community of writers and editors, Pacheco (2018) found that staff writers actively rejected, modified and accepted guidance of older CoP members,

while learning was permeated with discussions and practices about valued and valuable identities inside the newsroom (i.e., CoP). In a study about a CoP built for a cohort of Master students, the majority of which were enrolled in the online program, Cowan (2012) found that the usage of exemplary students from previous years as orientation instructors, and the existence and structure of the CoP itself was found to be vital for students' success in the program. Another study on graduate students participating in journal clubs, which were designed as a CoP, identified knowledge building, critical thinking, peer-learning and confidence gain to be some of the most direct benefits of participating in that particular CoP (Newswander & Borrego, 2009).

Female Participation in CoPs

A few studies used LPP within CoPs as a theoretical framework in research on female participation in different CoPs (e.g., Callahan & Tomaszewski, 2007; Cameron, 2009; Eckert & McConnell-Ginet, 1999; Ferreira, 2010; Holmes & Meyerhoff, 1999; Richard, 2011; Tomaszewski, 2004). From these studies, we learn that when female participation in a CoP is undervalued (Olson, 2015), denied (Lave & Wenger, 1991) or inhibited (Smith, 2009), it can influence how they choose to engage in those communities, which reflects literature on factors that influence women to leave CS majors.

I selected LPP within CoPs to study women's participation in their CS major, because the tenets of this framework do not blame marginalized people for being marginalized and they do not naturalize divisions of social inequity (Lave, 1996). In her study of CoPs of two STEM departments, for example, Ferreira (2010) found that female

graduate students were much more likely to have a positive view of the CoP if gender diversity was reflected in the organization of the department and there was collegiality among students and professors. In their attempt to understand how women participate in a male-dominant nonprofit organization, Callahan and Tomaszewski (2007) found evidence of two types of engagement: one based on individualism, where women emphasized their independent strategies in dealing with any emerging issues, and another based on sisterhood, where women emphasized the importance of personal and working relationships with other women inside the community. Additionally, women in science were found to be more engaged in a CoP if they had access to research opportunities in addition to meaningful coursework (Ceglie Sr., 2009). Skills developed in class, however, were found to be important for them to perceive legitimacy in connection to their daily activities (e.g., Ceglie, 2009; Guzdial & Tew, 2006).

I posit that attrition of women inside CS majors occurs when women do not find a way to become members of this CoP, despite being enrolled in the major. Alternatively, it could be that women who decide to leave this major were always on the margins of the community without proper access to meaningful learning opportunities or resources. It is my belief that to understand retention, we need to understand women who persist, as well as the factors, or enablers, influencing their ongoing participation.

LPP within CoPs is not without criticism. Some of the most common critiques say that it does not place enough emphasis on issues of power (Roberts, 2006), and/or it is too anachronistic and/or instrumental (Wenger, 2010). That is, it is not connected with history and it does not have enough analytical power. Roberts also pointed out the theory

does not explain how trust is developed inside a CoP, without which members may be reluctant to share. He also emphasized the possibility of CoPs being predisposed to absorb only certain types of knowledge as additional limits of CoPs. Li et al (2009) posited that lack of consistency in the interpretation of CoPs makes it difficult to describe and measure their effectiveness. To that end, some researchers are saying that we need better understanding of CoPs through more empirical work (Evans & Powell, 2007). This dissertation addresses that need.

Summary

Retention of women in CS majors has been widely researched. There are currently three distinct bodies of literature examining the problem of retention. Initially, researchers focused on the gender gap and the differences between men and women in CS. From these studies, we learn that women in CS lack prior experience, while at the same time, they have different self-perceptions and participation patterns in comparison to their male peers. Another body of literature focuses on examining factors embedded in the institution itself, such as faculty influence, departmental culture, and peer influence. Finally, there are some studies that focus on factors external to the institution, such as cultural norms and values, and family and peer influence. The problem with existing studies is that they seldom use a theoretical framework, often portray women as deficient in something and/or they draw conclusions from a mixed sample of men and women rather than focusing on women. This dissertation uses social theory of learning or learning as LPPin CoPs to study retention. The theory explains enculturation in a CoP

without putting the blame on the marginalized (i.e., women) and/or without naturalizing divisions of social inequity (Lave, 1996). On the contrary, it acknowledges that women's participation in a CoP can be affected when women are not valued, or when their participation is inhibited or denied, at the same time providing mechanisms for us to explain ongoing participation and the factors that influence it.

CHAPTER III

METHODS

Over the past 25 years, the research on the retention of women who major in CS has grown both in breadth and depth. However, as we found in previous research, the majority of empirical studies examining retention in this area focused on quantitative research methods. Most often, research was conducted through survey data (Pantic & Clarke-Midura, 2019). In addition, we found very few studies used an exclusively female sample and/or emphasized the voices of women who persist in their CS major. Therefore, the purpose of this dissertation study was to shed light on the issue of retention by (1) giving voice to the women who persist in the major and (2) employing a qualitative research design.

Research Design

The research design applied in this study is qualitative research design (Glesne, 2015). According to Maxwell (2012), understanding a particular context, processes and phenomena by which actions take place and the meaning individuals assign to them are some of the biggest advantages of this type of design. In the context of this study, I strive to understand the process of retention of women in CS and the meaning women assign to the resources and interactions systems available to them inside the CoP of their CS major and other CoPs that they belong to. Additionally, I strive to understanding different participation pathways that women follow.

I chose qualitative design because it is flexible to adaptation of inquiry and

responsive to new paths of discovery that may emerge from research as our understanding of the matter deepens (Patton, 2002). Considering that studies on retention of women in CS from the perspective of women who persist in their major are rare, the ability to remain responsive to new or unexpected findings is crucial. According to Marx (2016), qualitative research proves very valuable in STEM education studies when we need to focus on the individuals and the impact structural forces have on them.

Setting

The sample for this study was drawn from one mid-size university in the Intermountain West. According to the university website, in 2018 the university enrolled about 27,000 students in its undergraduate programs, 54% of which were women. In April of 2019, the CS department had 17 faculty members, seven temporary instructors and four staff members. Three of the faculty members and four of the staff members were female. The department had both undergraduate and graduate programs. Their undergraduate program consisted of the pre-professional program (62 credits course load distributed across Freshman and Sophomore year) and the professional program (58 credits course load distributed across Junior and Senior year of the program). Even though a CS major can be declared from day one, to qualify for the professional program, students needed to complete the pre-professional program first. In a personal communication from May 2017, department administration reported having 11 women (out of 106 students) in their Junior, and 23 women (out of 206 students) in their Senior year. In other words, women made approximately 10% of students in upperclassman standing, which is lower than the national average (NSF, 2017). Based on the department

website, racially and ethnically minoritized groups made 11% of the overall undergraduate population in 2015, while women made 8.8%.

Students' participation and learning in this department were supported by a number of clubs and organizations. As an example, students could join a variety of clubs, some of which are Association for Computing Machinery (ACM) and Association for Computing Machinery for Women (ACM-W), Free Software and GNU[2]/Linux Club, Robotics Team, Hack[UniversityName] . The Tutor Center, another organized support system run by senior CS students was open six days a week. From Monday to Friday, the lab was open for 11 hours and on Saturdays it was open for nine hours. The tutors provided help with specific programming problems, algorithm design or conceptual understanding, when needed. The CS Department is located on the top floor of the oldest building on campus and it has all the professor's offices, clubs, Tutor Center and the student lounge located on the same floor.

Sample

Considering the definition of retention presented in Chapter I, I used purposeful sampling for this study. Patton (2002) defines purposeful sampling as the one that selects participants from the most information-rich cases which illuminate the question under study. With that in mind, my sample consisted of ten female undergraduate students who have declared CS as their major and were in advanced stages of their undergraduate CS program (i.e., professional program of their major). More precisely, the participants in

[2] GNU is an operating system and an extensive collection of free software: https://en.wikipedia.org/wiki/GNU

this study were either Junior or Senior undergraduate students in a CS major of one mid-size university located in a rural area of Intermountain West. The number of participants has been estimated by taking into consideration the nature of my research design, as well as the low number of women enrolled into the CS major, particularly within the upperclassmen standing.

Nine women participated in all three phases of the study, and one participated only in Phases Two and Three. Participant characteristics in terms of age, academic standing, year major was declared, enrollment status, race, ethnicity, marital status, number of children, work status and place of origin are presented in Table 3. All the information for this table was drawn from the demographic survey, which was collected upon meeting them.

Table 3

Participant Characteristics

Participant pseudonym	Age (Mean = 21.8)	Academic standing	FTS	Racial and ethnicity	Marital status	EPT	Prior residence
Jane	22	Senior	x	Caucasian	Single	x	Nevada
Haley	25	Junior	x	Caucasian	Single	x	Minnesota
Adele^	19	Junior	x	Caucasian	Single	x	Utah
Joana	22	Senior	x	Latinx Caucasian	Single	x	Brazil
Shelby	21	Junior	x	Caucasian	Married	x	Arizona
Savannah	22	Junior	x	Caucasian	Single	x	Idaho
Beatrice	22	Senior	x	Caucasian	Single	x	Utah
Maggie	22	Senior	x	Caucasian	Single	x	Utah
Monica	23	Junior	x	Caucasian	Married	x	Utah
Erin	19	Junior	x	Caucasian	Single		Utah

Note. FTS = Full-Time Student; EPT = Employed Part-Time.

^ Participant did not participate in Phase I.

Recruitment

Participants for this study were recruited via e-mails through the CS department secretary. In addition, I attached flyers with information about the study on the notice boards and club doors across the department (see *Appendix G* for samples of recruitment material). Participants were recruited to participate in all the phases of the study, but the focus group schedules did not work for one of the participants. Since the recruitment strategies did not produce the needed number of participants, I also used snowball or chain sampling. Patton (2002) defines snowball sampling as a process of finding participants by asking well-situated people who a good participant would be. This sampling was done through one of the female professors in the CS department who reached out to the women taking her class, ACM-W leadership and other undergraduate women she knew. Each participant contacted me via email and verified that they met my established definition of commitment to the CS major. Next, I sent all the participants an invitation for participation in the study with two options for focus group signup. All participants completed the study and were compensated $10, $25 and $50 for their participation in focus groups, interviews and experience sampling method, respectively. More precise details on the actual procedure are provided in sections that follow.

Data Sources and Data Collection Procedures

To address the three research questions, and for the purposes of triangulation (Glesne, 2015; Maxwell, 2012), I collected data from a diverse set of women, all full-time students in advance stages of their degree completion. These women had a diverse background in terms of age, academic status, marriage status, work status, place of origin

and points of entry into the major (see Table 3 for more details on background). Also, for the purposes of triangulation, I collected multiple data sources: focus groups, interviews (in-depth and follow-up), journey maps and archives of daily experiences via Experience Sampling Method (ESM). This data was collected in Spring semester of 2018 (see Table 4 for a detailed timeline).

Table 4

Timeline of Data Collection

Time	Event	Activity	Phase
January 2018 (week 1 and 2)	Recruitment	Post flyers; Send emails; Schedule two focus groups; Sign up participants for their preferred time	One
January 2018 (week 2 and 3)	Focus groups	Conduct two focus groups; Collect demographic survey data; Schedule interviews; Send instructions for journey maps; Pay participants ($10)	One
January 2018 (week 4)	Interviews	Conduct individual interviews Collect journey maps Pay participants ($25) Set up SurveySignal accounts for ESM Schedule follow-up interviews	Two
January (week 5) and February 2018 (week 1)	ESM	Send daily signals to participants to collect data Collect data via Qualtrics and SurveySignal	Three
February and March 2018	Follow-up interviews	Check ESM data, focus and interview data and identify items that need clarification Design a set of questions for each individual participation, if needed Conduct follow-up interviews Pay participants ($50) Transcribe audio data	Three

The data for this study was collected in three phases. In Phase One, I conducted two focus groups and collected demographic data for 90% of the participants. The

purpose of this phase was to set groundwork for Phase Two and get a sense of the phenomena under study. At the same time, it served to establish initial relationships with the participants. In Phase Two, I conducted ten one-on-one in-depth interviews, collected the journey maps and the remaining demographic data. In Phase Three, I collected sample logs of women's daily activities and I conducted ten one-on-one follow-up interviews. The following text provides a detailed description of Phases One-Three, different methods used to collect data, as well as data collection procedures used during each phase.

Phase One

Research on the underrepresentation of women in CS education is a newer topic (Singh et al., 2007) with only a few studies focusing on women who persist (e.g., Dee et al., 2009; DuBow et al., 2017; Ragsdale, 2013; Rosson et al., 2011; Wilson, 2002). Therefore, I began this dissertation study by gaining better understanding of the issue of retention in CS and by laying some foundations for future work. Beginning Spring 2018 semester, I conducted two focus groups with women who have been recruited based on the recruitment criteria afore mentioned. Each focus group began with a brief hand-written survey (see Appendix F for a full survey) where I collected basic demographic information from each participant.

The goal of the focus groups was to establish initial connections with the population of CS women at these universities, but also to develop some initial understandings of how women in CS majors perceive, feel and think (Krueger & Casey, 2014) about their CS major experience and their personal pathways towards degree

completion. In addition, this phase was designed to help me lay the groundwork for Phase Two of this study.

Two focus groups were scheduled during the second and third week of January in 2018. Both groups were held on the university campus. Participants signed up for their preferred focus group time through an online survey. I sent a link for both events to each individual participant via email with clear instructions on how to sign up for one of the two events. Even though they had a choice of two events to sign up for, the maximum number of participants in each group was limited to five participants. The goal of setting a limit was to secure small group size with optimal engagement from all participants. First focus group event was attended by four, while the second event was attended by five participants. At the beginning of the focus groups, all the participants completed the demographic survey (see Appendix F).

During the focus groups, all the participants were asked open-ended questions about their experience in the CS major. These questions were theory-driven. That is, they were designed from the perspective of the LPPin CoPs described in the *Theoretical Framework*. The questions targeted different aspects of CS CoP that could have influenced retention of these women, as well as what their LPP through CS major looked like. The questions focused on students' pathways throughout the major, factors that influenced their commitment, the response of the community to their participation attempts, the type of support that they received, and the meaning that women assigned to who they were or who they needed to be in order to persevere in this major (see Appendix A for a full focus group protocol).

Focus group sessions were audio recorded and transcribed for further analysis. Each participant was compensated with a $10 Amazon gift card for their participation in the focus group. In addition, refreshments (pizza, soda and water) were served prior to each focus group session. At the end of each focus group, I scheduled one-on-one interviews with each individual participant.

Phase Two

Two weeks into the Spring 2018 semester, I proceeded with Phase Two of this project. The goal for this phase was to tap further into individual participants' emotions, a research aspect that is considered to be a disadvantage of focus groups (Krueger & Casey, 2014) and an advantage of more personal qualitative methods, such as an interview. In this phase, I collected journey maps and interviews on individual pathways through women's ongoing participation in their major. The assumption was that interviews would give me access to participants' motives, values, concerns and needs (Glesne, 2015). Interviews allowed me to understand what the process of becoming a member of the community looks like from these women's perspectives.

The main purpose of Phase Two was to answer the first and third research question proposed in this study and provide insights on the second research question. Data collected in the in-depth interviews and journey maps was used to map out different pathways that women adopted during their CS studies. It also helped me identify the factors that strengthened their commitment to the major along the way. More specifically, I looked into the interactions, activities, resources and practices that were transformative to their ongoing participation in CS.

Ten one-on-one interviews were conducted during the third week of January in 2018. At the time of the interview, all ten women were enrolled into the CS major as full-time students. They were either Juniors or Seniors. One of these women, who did not attend any of the two focus groups, completed a brief hand-written survey (see Appendix F) at the beginning of her interview, where she provided basic demographic information. Women who participated in Phase One of the study were not given the survey at this point, as they completed it at the beginning of their focus group events. Interview sessions were approximately 60 minutes long. All interviews were conducted in English. They were audio recorded and later transcribed for further analysis. The transcriptions of the interviews were done through an online transcription services provider.

Prior to coming to the interview, I instructed the women via email to come to the interview prepared. The preparation entailed constructing an illustrated map of their journey through the CS program that they drew themselves. The goal of the "pre-interview" instructions was to avoid imposing my own biases during the journey map activity. Using drawings to map one's journey through school is a technique initially used by Nyquist et al. (1999). This technique has the power to provide "powerful glimpses into the realities" (p.18) of student lives. The participants were provided with written instructions adapted from Nyquist et al. via e-mail (see Appendix B), which asked them to pay special attention to those moments on their CS journey that strengthened their commitment to the major or supported them in their persistence. Journey maps were selected because they have the power to provide continuing data on the whole process of the participation of women in their CS major, beginning with their enrollment into the

program all the way to the moment of their interview with me.

The interview itself consisted of two parts. At the beginning of the interview, the participants were asked to share their journey map and narrate their story of persistence (Meyer & Marx, 2014). This part of the interview was focused on the drawings (i.e., journey maps), where I relied on student driven narratives. Prompting was used rarely and only when interviewees did not point out what influenced them to overcome an obstacle mentioned in their narration (e.g., *What helped you persist in that particular moment?*) or when further explanation was needed. During this part of data collection, I took a digital image of the drawing and saved it as an artifact for further analysis. Physical copies of their drawings were also collected.

In the second part of the interview, the participants were asked a series of theory-driven questions (see Appendix C for a full interview protocol). The goal was to discuss different practices and interactions within the CoP of their CS major that could provide a more complete picture of their ongoing participation in this major. All the questions were theory-driven based on the theoretical framework discussed in the *Theoretical Framework* section of Chapter II of this dissertation. Questions were carefully crafted to identify the most transformative aspects of their learning and ongoing participation experience (Ropes, 2011). Each interviewee was given a $25 Amazon gift card upon the completion of the interview, as a compensation for their participation in this phase of the research. At this point, I helped each participant sign up for the third phase of this study through SurveySignal website. We tested the communication between the signal service and their phones, and we scheduled a follow-up interview at the same time.

Phase Three

Phase Three started on the day following the in-depth interviews. This day differed from one participant to the next. Phase Three consisted of two parts: survey responses to daily signals (ESM) and a follow-up interview.

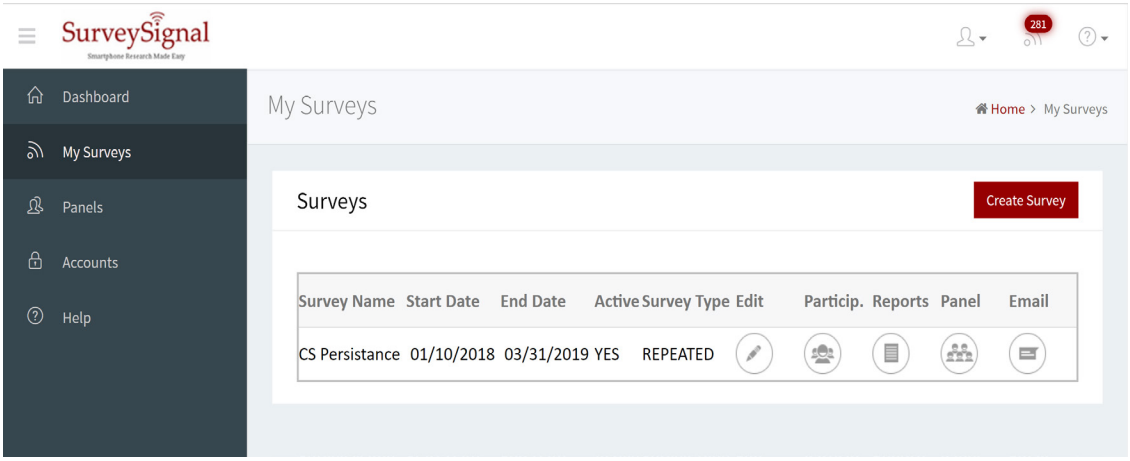
Experience Sampling Method (ESM) and Debriefing. This study attempted a more holistic approach to researching the phenomenon of retention of women in CS, one which would capture some unanticipated factors influencing retention in addition to factors already identified in literature. For that reason, sporadic observations of their daily routines and interactions in one context did not appear appropriate for this study. Instead, I used Experience Sampling Method (ESM; Larson & Csikszentmihalyi, 2014) as an observation method. The advantage of this method was that it obtained reports on people's everyday experience as it occurred in real time, which minimized the effect of reliance on memory (Larson & Csikszentmihalyi, 2014), increased information accuracy, and was less obtrusive than regular observations done by a person (Weisner et al., 2001), as there was no observer following them around. ESM was chosen because it had the power to provide more details on women's engagement across different CoPs, that is, the interactions and resources that they are using and that are not necessarily part of their major. In addition to helping me answer RQ2, ESM complemented and cross-validated the findings from other data sources in this study.

ESM is an innovative observation technique that can be applied via a variety of software (Conner, 2015). For the purposes of this study, I chose SurveySignal (see Figure 1 for a preview) software, one of the most affordable, reliable and customizable solutions

for ESM, according to Hofmann and Patel (2014).

Figure 1

SurveySignal Interface



All the participants in Phase Three were recruited from Phase Two. Prior to signing up participants for Phase Three, I opened an account on SurveySignal, set up survey configurations and linked it to a brief eight-question survey in Qualtrics (see *Appendix D* for a full list of questions included in this survey). All the questions in the survey were adapted from studies using ESM (e.g., Schneider et al., 2016; Weisner et al., 2001). The survey was set up to send one text signal to participants' cell phones randomly five times a day (between 8 am and 10 pm, which will be referred to as "waking hours") over a period of two weeks (14 days). Upon receiving the signal, the participants had limited time (30 minutes) to provide systematic self-reports on their ID number, where they were, what they were doing, who they were with, how typical that activity was, how it related to their CS major and how they felt in that moment. The last

question asked them to explain why they felt the way they did. The system was also set up to send a reminder to unanswered signals 15 minutes after the original signal. Both signals expired within 30 minutes of the original text. In other words, if the participants did not answer the prompt in the proscribed time interval, the data point was considered missing.

Upon clicking on the link embedded in the text signal they received, the participants were taken to a Qualtrics survey. Each survey took approximately two to three minutes to complete. Survey submissions were automatically recorded in Qualtrics, while their participation (completed or not) was saved on SurveySignal server as a percentage (aka "response rate"). In addition, SurveySignal recorded the date and time of when each signal was generated, for whom it was generated, as well as at what time the participant responded. If a signal was not replied to, the cell in the "time reply" column of the output was left unpopulated. At the same time, the output in Qualtrics was populated by the day (1-14) and order (1-5) of the signal in addition to the information asked in the survey. Participants provided their ID number each time they responded to the survey. This made all entries linkable to individual participants.

Participants were instructed not to answer a prompt if they were driving or were in any other position where texting would jeopardize their well-being. Each woman participating in ESM observations was compensated with a $50 Amazon gift card upon a successful completion of the task. Successful completion was defined before the beginning of the study to be 80% or above. The threshold for financial compensation was communicated both via the consent form they signed, and orally, after Phase Two, when

we worked on setting up the ESM experience for them. No participant reported that this experience would expose them to additional phone bill expenses. The average response rate in ESM part of the study was 91.71% (Min = 84.29%, Max = 98.57%), which resulted in a total of 640 survey entries across ten participants.

Debrief Interviews. To secure interpretability of ESM data, I conducted a short debrief interview with each participant one day after their 14-day long ESM experience. The purpose of this data collection was to clarify any confusing entries, missing data points and/or collect any other information that emerged as important over the two weeks. Debrief interviews were 15-20 minute long. They were conducted in English and audio recorded. Debrief interviews were unstructured and catered to the experience of each participant individually. Therefore, there was no set protocol for this data collection strategy. Appendix E, however, provides a list of some questions that were asked frequently during this session. I transcribed all the interviews verbatim upon their completion.

Data Analysis

Descriptive Statistics

All participants completed a demographic survey at the beginning of the study. Survey data has been summarized in Table 3. ESM frequency of participation was automatically saved on the SurveySignal server (see Table 5 for details on participation in the ESM experience). ESM survey answers, however, were recorded in Qualtrics.

Table 5

ESM Frequency of Participation

Pseudonym	Frequency of ESM completion (%)
Jane	90.00
Haley	87.14
Adele	85.29
Joana	85.71
Shelby	97.14
Savannah	85.71
Beatrice	94.29
Maggie	97.14
Monica	97.14
Erin	98.57

Once the 2 weeks of data collection expired, ESM data was downloaded from Qualtrics onto my computer, where it was cleaned and organized to facilitate further analysis. To clean the data, entries that represented the same entity (e.g., location) but were labeled differently were organized into the same category. For example, category *Home* included all entries which referred to participants' homes, such as "*in my apartment*," "*in my room*," "*at home*," etc. After data cleaning, I collapsed all related categories into the same category. For example, all entries of any location on campus not related to taking a class (e.g., *at the library, in campus cafeteria*) were labeled as *Campus (other).* As an example, all school-related activities such as "*attending class*," "*doing homework*," "*studying*" and similar were collapsed into one category called *School Work.* In order to explore the data, I created frequency tables and charts, as well as bar graphs of some intersecting relationships between different items.

Upon closer examination of the data from this analysis, I have concluded that the

majority of it does not contribute to answering the three research questions in this dissertation study, one of the reasons being lack of benchmark data due to the innovative nature of this methodology. For that reason, only the data on women's participation in other communities was included in the analysis of RQ2. The remaining data was not reported in the Results section. An overview of the analyses, however, is provided in Appendix H together with charts and summaries of their daily routines.

Analysis per Research Questions

Data analysis of qualitative data sources was conducted in several stages of interpretation, reflecting the constructs, concepts, language and theory used to structure the study in the first place (Merriam, 1998). The following text provides a thorough description of different analytical strategies used to answer each individual research question. Table 6 outlines the relationship between different RQs, data sources and data analysis strategies. To answer RQ1 and RQ2, data was coded cyclically in three waves. First, I took the opportunity to pre-code the data by circling, highlighting, bolding, and underlying the most striking and illustrative quotes and examples on the hard copy of data outputs (Saldaña, 2015). Pre-coding was accompanied by some preliminary jotting down of potential themes and observations and it allowed me to familiarize myself with the data overall, as well as develop some initial understanding of the phenomena being examined.

For the first and second cycle of coding, I used professional software for qualitative and mixed methods data analysis, called MaxQDA (see: https://www.maxqda.com/). After reading and interacting with the data during the pre-coding process, I used a

combination of open and In Vivo coding to start analyzing the data (Patton, 2002). The unit of analysis in this phase was theory-driven and it included all meaningful interactions and practices (RQ1) that contributed to participating women's persistence in their CS major. "Meaningful" here is defined as "positively contributing to persistence." For RQ2, the unit of analysis was any utterance where women described or mentioned different communities they belonged to. All the entries from the SurveySignal ESM experience where participants different communities that they belonged to outside their major were also coded for RQ2. Table 6 presents all the primary data sources used to answer both RQ1 and RQ2.

Table 6

Relationship Between RQs, Data Sources and Data Analysis Strategies

Research question	Primary data sources	Data analysis
RQ1: Which factors (i.e., enablers) influence women's ongoing participation (i.e., retention) in their CS majors?	Focus groups Interviews	Initial coding Open and In Vivo Coding Axial Coding
RQ2: What kind of external communities do they belong to as they work towards the completion of their major?	Interviews ESM Follow-up interviews	Initial coding Open and In Vivo Coding Axial Coding
RQ3: What different pathways of participation do women follow as they work towards the completion of their major?	Journey maps Interviews	(Cross-)case study analysis Narrative analysis

Open coding is recommended for primary identification of concepts and review of the data corpus. It "involves discovering patterns, themes, and categories in one's data" and is typically done in the early stages of data analysis to develop manageable classification or a coding scheme (Emerson et al., 1995, p. 453). Per recommendation of

Emerson et al., the accent in this stage is not on how categories go together, but more on identifying and naming important occurrences and their significance. To secure transparency of women's voices in the study, initial coding was employed in combination with In Vivo Coding wherever possible. Saldaña (2015) defines In Vivo coding as coding that "draws from the participants' own language for codes" (p.84), which was particularly useful in describing the culture and other meaningful CoP practices that were integral to women's persistence in the CS major. This phase resulted in a total of 885 codes, after which I proceeded to the second cycle of coding.

The goal of the second cycle of coding was to understand the relationships between the codes identified in the first cycle and consequently, the themes and theoretical organizations emerging from the data (Saldaña, 2015). In the second cycle of coding, I employed axial coding, where I focused on organizing codes into related categories and subcategories (Patton, 2002) which best answered RQ1 and RQ2. By moving from open to axial coding, dominant and relevant patterns (aka categories) were identified and organized to best answer the proposed research questions (Patton, 2002). This coding cycle contained several iterative cycles of review and revision to achieve the utmost saturation of the findings. At the end of the second cycle, 512 codes were organized into 14 categories aiming to answer RQ1. Upon closer examination, one of the categories (*Staff Support*) was excluded, as all the codes seemed provoked by one of the interview questions (*Who checked in with you to make sure you were progressing?)* alone and did not show up anywhere else in the interview. In the end, this analysis resulted in a total of 13 categories and 503 codes for RQ1. These categories were divided into two

theory-driven groupings: *Social Interactions* and *Practices.*

Under Social Interactions, I identified four categories of social factors that influenced retention of women in my sample: *Peer Support*, *Faculty Support*, *The Role of Clubs in the Major*, and *Tutor Support*. I chose to label these interactions as "support" because they were mostly positive. Table 7 outlines the codebook for this group of factors influencing retention. All the codes, definitions and examples are given inside this table. The categories themselves are described in detail in Chapter IV (Results) and discussed in Chapter V (Discussion and Conclusions).

Under Practices, I identified nine different practices that emerged from the data: *Gaining Legitimacy, Establishing Balance*, "*Lone Wolf," Finding a Job*, *Proving you Belong*, *Abandoning Perfectionism*, *Finding Online Resources*, *"Just a Really Good Class"* and *Other.* Table 8 outlines the codebook for this other group of factors influencing retention (Practices) with its codes, definitions and examples. All these categories are described in detail in Chapter IV (Results) and discussed in Chapter V (Discussion and Conclusions).

For RQ2, 373 remaining codes were organized into four categories of External Communities that women belonged to. These included: *External Peers*, *Family*, *Co-workers*, and *Other.* Table 9 outlines the codebook developed to answer RQ2 with all its codes, definitions and examples. All the categories that emerged in connection to RQ2 will be described in detail in the *Results* section.

To calculate intercoders' reliability, an additional researcher was trained in the coding procedure and logic using Tables 7-9 and some additional examples. After

Table 7

Codebook for Social Interactions Influencing Retention (RQ1)

Code	Definition	Example
Tutor support	Women mentioning how the help and encouragement of tutors in CS Tutor Lab influenced their persistence	Jane*: "As a freshman or sophomore, I went to the tutor lab a lot and so that's all just juniors and seniors helping you. That was huge for me. I wouldn't have made it through without the tutor lab. They are technical help, but also, they're encouragement of like… CS2 is hard for everyone. You're gonna get through it and it'll be okay after that."* (interview)
The role of clubs	Women mentioning the importance different CS and university clubs and organizations that they were active in (e.g., ACM-W, University ambassadors) had on their persistence	Shelby: "*when I was a freshmen year, I was in a … actually, you were in there with me* (talking to another woman)*, the Women in CS club and that was actually big support for me, cause we'd all get together and like the department head, I think, she came too, but we would talk about different issues that we were facing. So that was a big support for me*." (focus group)
Faculty support	Women reporting different ways in which faculty members influenced their persistence	Haley: "*I am working on some research right now. The professor is actually in mechanical engineering. It's not even in the CS department and um, she is always great at you know, being like, not only a support in school but you know, an emotional support, … you know, everything, she is always making sure that I'm ok, so that's helpful, a big thing for me It's really helped me get through the major.*" (focus group)
Peer support	Women reporting different ways in which their peers (other CS students) helped them persist; **these exclude tutors and or women they met in ACM-W*	Savannah: "*I need to have at least one or two friends in the class who I feel like I can sit next to. It's a lot harder for me when I feel like I've walked into a class of people that I don't know and then…. I honestly sometimes start to feel a little bit intimidated, like people are gonna judge me on my performance, because they don't know who I am, but if I have someone to go and sit next to and feel comfortable asking questions, like they are not gonna be like "oh, this is just like another dumb girl who is just trying to like, you know… figure out the CS thing even though she has no clue and everyone is gonna hire her because she is a girl!" Like, I don't wanna feel like that. I wanna have a comfortable friend who like I can ask something "Oh, what was that thing?" like a weird stack again and then he can explain it to me, or she can or whatever… and you know, it's just… I feel like I have a friend in the class*."

Table 8

Codebook for Practices Influencing Retention (RQ1)

Code	Definition	Example
"Just a really good class"	Women listing examples of classes that kept them interested in the program and/or provided a valuable learning experience (authentic practice)	Joana: "*Then it was like…. I wrote down some classes that was like a small reason why …. Then some classes a like…. I am having a little bit more fun in this class and I wrote "falling a little bit more in love with this one class" and it was like small little details into this like midlevel classes.*" (journey map)
Finding Online Resources	Women reporting to develop and rely on Internet research skills to locate, evaluate, and use needed information effectively	Maggie: "*Learn how to Google the right questions."* Beatrice: "*Yeah, learn how to Google is a big one because a lot of times people would Google really badly.*" Savannah: "*Yeah, and you are like…*" Maggie: "*It is just right there and they ask you…"* Interviewer: "*How do you Google badly?*" Monica: "*You wouldn't think it's possible but it really is* [*laughs*]. *Certain key words!!"* Maggie: "*…like when they get certain errors like throwing in specific names for the errors and that sort of thing where like… that's something you wrote exactly and so it's not gonna match word for word with someone else 'cause if it's like your variable and something like that… so you gotta extract what's from … what's your error part and what's like the global error part, so then you Google the global one."* Everyone: "*Yeah*!" (focus group)
Abandoning perfectionism	Women testifying about how they had to change their mindset from trying to be the best in the whole class to 'giving their best' which was reflected in being ok with asking for help, dropping a course and or not knowing everything	Maggie: "*I think we also compare ourselves to the best in the class and sometimes we are the best and sometimes if we compare ourselves to the guys who've been doing this forever, it's hard to…. I mean, we are obviously at a disadvantage there, but if we kinda forget about that… for me especially, if I forget about that I am like "ok, I just need to do the best I can!" that's how I have been able to persist*." (focus group)
Proving they belong	Women talking about different strategies they used to prove to themselves and their peers that they belonged in the major, such as open confrontation and/or working harder (action accompanied by feelings of self-doubt)	Jane: "*I never let anything go, I always attack that. Dead on. I am just like "Hey, that's inappropriate and I am smarter than you are so that's why I got the interview!"* [laughs] *"That's not… like I don't like it when people say that 'cause that's like… all of your hard work is like marginalized to just your gender like…. The thing you didn't even choose*." (focus group)

(*table continues*)

Code	Definition	Example
Finding a job	Women testifying about how finding a paid positions contributed to their competence building and retention in the major, by helping them imagine themselves in the industry in the future and or developing self-efficacy	Jane: "*Being in jobs helps a lot, like over the summer I had a pretty good internship at like a really big company and so … they had a lot of like opportunities for like personal growth. A lot of organizations in the company that supported you with different things you wanted to learn so...*"
"Lone wolf"	Examples of women identifying themselves as independent learners or learners who enjoyed solving problems on their own	Maggie*: "I had friends, but I did most of the work … unless it's a group work, by myself. But I never. It wasn't that I wasn't like challenged, but I felt like I had that kind of a background that I felt comfortable solving the problem myself that… I don't know, most of my assignments, like I… I don't know. I didn't work with people as much as some other [students]. I just kind of went home and worked on my assignments (…) I think it is partially just my personality of …. Like I love people but … I … work with myself best. I prefer… I don't know, like … when I like show something to someone like it really helps and I don't know…. Just through this major in particular, I know in my first couple, I worked in groups a lot more and in this one, I just kinda did a lot of it myself. So… I mean there was a community that like I was friends with and like provided me moral support and there is obviously like group projects where I work with people"* (focus group)
Establishing balance	Women reporting conscious introduction of a CS-unrelated minor, exercise, and or different activities to maintain work-life balance with their major	Adele: "*I try to balance kind of… I have this, oh, what's the word, I'll use the word theory. Um… to kind of have balance. A physical balance or be physically active. And an academic balance, so do well on homework and a spiritual balance, so kind of focus on my church, as well. And I find that, if I kinda have the balance with my body as well as my mind, then I can succeed in what I wanna succeed in, so computer science.*" (follow-up interview)
Gaining legitimacy	Women naming different ways in which they got acknowledged or found acknowledgement, such as at work, in school, in themselves etc.	Shelby: "*I feel like [colleague] helps me a lot, because he's super supportive. And he like believes that I can do things. Yeah, for example, he just asked me to do—write unit tests. I was kind of like, I have no idea what unit tests are. He kind of told me, "Well, just get started and we'll see how it goes." I don't know. That was kind of helpful to me, because it made me just jump in and try it. It actually wasn't* (…) *Just his faith in me helps me believe in myself, cuz he's kind of like, "Oh, you're a programmer. You'll know how to do this." And then obviously if I have questions or if I get stuck he's very willing to help me figure it out."*
Other	This category includes all the factors that were mentioned only once or only by one person	Adele: "*I don't really let it bother me. Not all of 'em are like that. I just find guys that aren't as arrogant about their knowledge or superiority.*" (interview)

Table 9

Codebook for Communities to which Women Belong Outside their Major (CoP)

Code	Definition	Example
External peers	This category includes all external peers (e.g., roommates and friends) who were identified as a community they belong to (that did not share their major)	Participants reported spending 15% of their time with their roommates, overall. Participants reported spending 4% of their time with their non-CS, non-roommate friends across all 10 cases, overall.
Family	This category includes all the instances when family members, such as partner, or mother and father, were identified as part of their active community	Interviewer: "*Who makes your community?*" Maggie: "*My family, my boyfriend, of course, are always asking how things are going, that sort of checking in, and making sure things are going."*
Co-workers	This category includes all the instances when co-workers were identified as a community they belong to.	Participants reported spending 6% of their time with their co-workers across all 10 cases.
Other	This category includes all other mentioning of people in their lives, such as church people, volunteering colleagues, and other university people	e.g., Participants reported spending 1% of their time with church-people across all 10 cases, overall.

receiving the training, the coder was presented with approximately 20% of codes for each of the three categories (Practices [n = 67], Social Interactions [n = 34], and External Communities [n = 75]), which they then coded deductively according to the existing categories (Patton, 2002). Codes were chosen randomly after generating three sets of random numbers. Upon receiving the coded document, I created a matrix in Excel and calculated Cohen's kappa (κ) using Cohen's (1960) formula for "interjudge agreement" (p.46) ($\kappa = \frac{\Pr(a)-\Pr(e)}{1-\Pr(e)}$). Cohen's κ for *Practices* (RQ1) was greater than 0.66, indicating a "moderate" level of agreement (McHugh, 2012), while Cohen's κ for *Social Interactions*

(RQ1) and *External Communities* (RQ2) was 0.95 and 1, respectively. Both of these indicated "almost perfect" level of agreement (McHugh, 2012). Upon closer examination of areas of disagreement with the Practice category during a follow up conversation with Coder #2, it became clear that they did not have a clear understanding of the concept of "legitimacy," and that they miscoded two of the categories (e.g., they coded "abandoning perfectionism" category as if it was called "striving for perfectionism"). At that point, we discussed all the differences in our codes for *Practice* and Coder#2 received additional explanations of the definitions of all the categories included in RQ1a (*Practice*). When Coder#2 felt confident that they understood the codebook, they received a new set of 67 random codes, which they then coded deductively. Cohen's κ for *Practices* (RQ1) was calculated with this new set and was greater than 0.87, indicating a "strong" level of agreement (McHugh, 2012).

Research Question Three focuses on individual journeys of women who persisted in their CS major. In order to emphasize the richness and nuances in different experiences of women's ongoing participation, I used cross-case study analysis (Yin, 2009) by focusing on the most prominent milestones on their pathway, many of which aligned with Frieze and Quesenberry's (2015) "ongoing journey of women" (p. 43). These included prior programming experience, motivation to study CS, entry points into the program, initiation experience into the program, initial support system on the periphery of the community, and two topics that emerged from the data as important for most cases. After presenting the cross-case study analysis, I chose five of the richest cases to illustrate some of the most typical pathways of ongoing participation. These were analyzed using

narrative analysis (Merriam, 1998), which highlights women's experience through their own narration as they tell their stories of persistence. Each story is supported and illustrated by a journey map that they provided, excerpts from their testimonies and theory-driven interpretations. Five remaining case studies are also available in Appendix I.

Ethical Considerations

To ensure that necessary ethical requirements have been fulfilled, this dissertation study was submitted for review to the Institutional Review Board (IRB) at Utah State University in Fall 2017. To guarantee compliance with IRB guidelines and regulations, I obtained IRB-approved informed consent forms from all the participants prior to collecting any data. The form was also presented to all the participants, so they can inform themselves about the purpose, procedure, benefits and potential risks of the study. I also informed them about the anonymity of their participation and confidentiality of data collected. They were told that they can withdraw from the study at any time with no consequences. However, one participant did not receive compensation for Phase One of the study, as they did not participate in it. The fact that participants would not be compensated for those parts of the study that they did not participate in was communicated to them both at the beginning of the study and at the beginning of each phase of data collection.

Trustworthiness

Alternative explanations can jeopardize trustworthiness and credibility of research

studies (Maxwell, 2012). This section describes all the measures I took to secure both. To secure trustworthiness of description, I triangulated (Glesne, 2015; Patton, 2002) data from diverse individuals (see Table 3 for Participant Characteristics) using a variety of methods, such as focus groups, interviews, journey maps and ESM observations. My approach of combining focus groups with interviews had a twofold purpose: to help me set some foundational work for this study, but also to allow for insights into the phenomena both from group and individual perspective. Both focus groups and interviews were audio recorded and transcribed to secure correctness of data collected. To minimalize the pressure of my own presence on the creation or outcome of the journey map, I instructed the participants to draw the maps at home and then bring them to the interview. During that part of the interview when participants talked about the drawing (Part One of the interview), I made a conscious attempt to minimize my engagement in the conversation and avoid leading the participants. Finally, ESM had been chosen for two reasons: as a less intrusive way to conduct observation, which has the potential to diminish reactivity (Maxwell, 2012), but also as a way to consider alternative or discrepant data which was not predicted by the interview protocol designed. Such data was later discussed in the follow-up interview.

To secure rigor, I made a serious and systematic attempt to learn (Maxwell, 2012) how women in CS make sense of their persistence. This included considering alternative or discrepant data, as mentioned above, but also getting feedback from a variety of sources, both members and non-members of the CS community. Members of the community were consulted through a method called member check (Glesne, 2015;

Maxwell, 2012), where I discussed the emerging themes with a woman in CS during early stages of data analysis. During this conversation, the member provided several useful insights on the categories that emerged from this data. I also made a conscious attempt to understand how my own biases and values influenced my interpretation of the data. According to Patton (2002), one way of controlling or minimizing your biases is to emphasize empirical findings and separate them from your own perceptions. That is, one needs to make sure claims are richly supported with empirical evidence emerging from the study. This strategy has been applied throughout the data analysis process. According to Maxwell (2012), you also need to be reflexive of your own conduct and the types of conclusions that you as an individual make. Rather than trying to eliminate yourself from the research, which is impossible, I always tried to understand how my own values influence my own research conduct and use such understanding in the most productive manner possible. To that end, the following section provides an overview of my perspective.

Researcher Perspective

Growing up I was mostly surrounded by strong independent women who always instilled in me that I can be whatever I want professionally. In our house, if a piece of furniture needed to be put together, we would simply do it ourselves, and if something was broken, we would fix it. I always assumed that if you put enough effort into learning something, you can succeed in any profession regardless of gender. Even though I grew up in a rather monochromatic culture in terms of diversity (Schnabel, 2013), my own family was both bilingual and a minority, which made me naturally drawn to diversity in

other people. Perhaps as a result, my own work has always focused on inclusion and diversity, through projects on ESL learning, international communication, gender equity and other work with different minoritized groups. Even my own education has crossed disciplinary boundaries several times. I am a doctoral student in a College of Education working at the intersection of Education and Computer Science, but I also have a bachelor's degree in English Language and Literature, and an MS in Communication.

Regardless of my upbringing and high grades in STEM-related classes, I somehow avoided STEM careers for a long time. As an example, I took several programming classes in high school and I still could not envision myself as a computer scientist, but opted for arts, humanities and social sciences. I rediscovered programming during an internship, where I worked as a communication specialist maintaining their social media and website content. Despite my understanding of coding, I never fixed the broken links myself, but made notes for the "tech" person to do it. One day, after receiving one of my emails, he walked into my office and threw a heavy book onto my desk and said "*Here! You need to learn how to do this*!" I looked at the book, which said Introduction to HTML, and immediately panicked. My colleague, however, was dead serious.

And so, my journey of programming began. This time for real. My knowledge of HTML and CSS brought me my next job, where I developed more programming skills and started taking programming classes. This led to a couple of research assistantships on projects where the goal was to broaden participation in CS by teaching middle and high school youth how to program with platforms such as Scratch and/or App Inventor. But as

my knowledge in CS grew, I could not stop but wonder why I never really discovered programming before. Part of it was surely for economic reasons. Growing up with a single parent and a younger sibling, we were frugal with money. I got my first computer when I finished college and started working. And even then, it was my brother who used it mostly. Interestingly, he eventually ended up studying CS. Did someone convince me this was not a profession for women despite my mother's strong encouragement? Or was I exposed to subtle comments of discouragement and teasing from my peers? Even today I am not certain of the reasons behind my lack of self-efficacy to pursue this career. But one thing I do know. I never lacked interest in CS, neither was I bad at it. But at some point, I started believing that CS is not a career for me, or that I could not excel in this major.

Personal reflections on my own career choices led me to get interested in recruitment and retention of women in CS. I caught myself gravitating towards case studies of girls in our programming camps because I felt I could relate to them. I also started reconstructing some of my own struggles through the experience of the girls we were teaching, and I took a very supportive and encouraging approach to teaching them or talking to them about CS. As time passed by, I made it my goal to empower more women to pursue CS. At one point, I realized that my experience is not enough for me to be able to do this effectively. I realized that I needed to learn from those who have succeeded, which is one of the biggest motivations I had for this study.

Summary

This study employed a qualitative research design where data was triangulated by using several different data sources collected from ten women (upperclassmen in a CS major) with diverse backgrounds. The study was designed to collect data in three phases. In the first phase, I conducted two focus groups. In the second phase, the women participated in individual in-depth interviews and produced journey maps of their ongoing participation in CS. In the third and final phase, the women participated in the ESM experience and gave a brief follow-up interview. Women were recruited from a mid-size rural university in Intermountain West where women make 10% of the cohort in upperclassmen standing. Data for RQ1 and RQ2 was analyzed using a combination of initial, In Vivo and axial coding, while data in RQ3 was analyzed using (cross-)case study and narrative analysis. This chapter also discussed the measures taken to achieve trustworthiness, as well as a section on my perspective, as a researcher.

CHAPTER IV

RESULTS

Demographic Information

A sample of ten women completed the demographic survey for this study (see Table 3 for details). All the participants were either Juniors (60%) or Seniors (40%) with a declared major in CS and an average age of 21.8. At the time when this study was conducted, 90% of the women were working part-time in addition to being full-time students. The majority of the women were Caucasian (90%), while one declared herself as LatinX and international. Though not racially and ethnically diverse, this sample is reflective of the racial and ethnic make-up of the area. Geographically, women came from five US states (Utah, Arizona, Nevada, Minnesota and Idaho) and one non-US country, Brazil.

Factors Influencing Retention

Research Question One focuses on examining different factors that influenced retention of women inside the major itself. Using the lens of LPP within CoPs, I focused on understanding different types of social interactions and practices within the CoP of their major that provided an appropriate context for their ongoing participation (i.e., retention). To that end, findings for RQ1 will be organized in two sections: Social Interactions and Practices.

Social Interactions Influencing Retention

After analyzing the data (for more detail see *Data Analysis* section in Chapter III), four different types of interactions emerged as important inside the major for women's retention in CS: *Peer Support*, *Faculty Support*, *The Role of Clubs*, and *Tutor Support* (see Figure 2 for frequencies with which those codes appeared). The themes in this section will be presented in ascending order from least to most frequently mentioned support. Table 10 shows the distribution of each type of interaction by gender. The importance of gender will be discussion in each corresponding section.

Figure 2

Frequency of Codes for Social Interactions that Enabled Participants' Retention (RQ1)

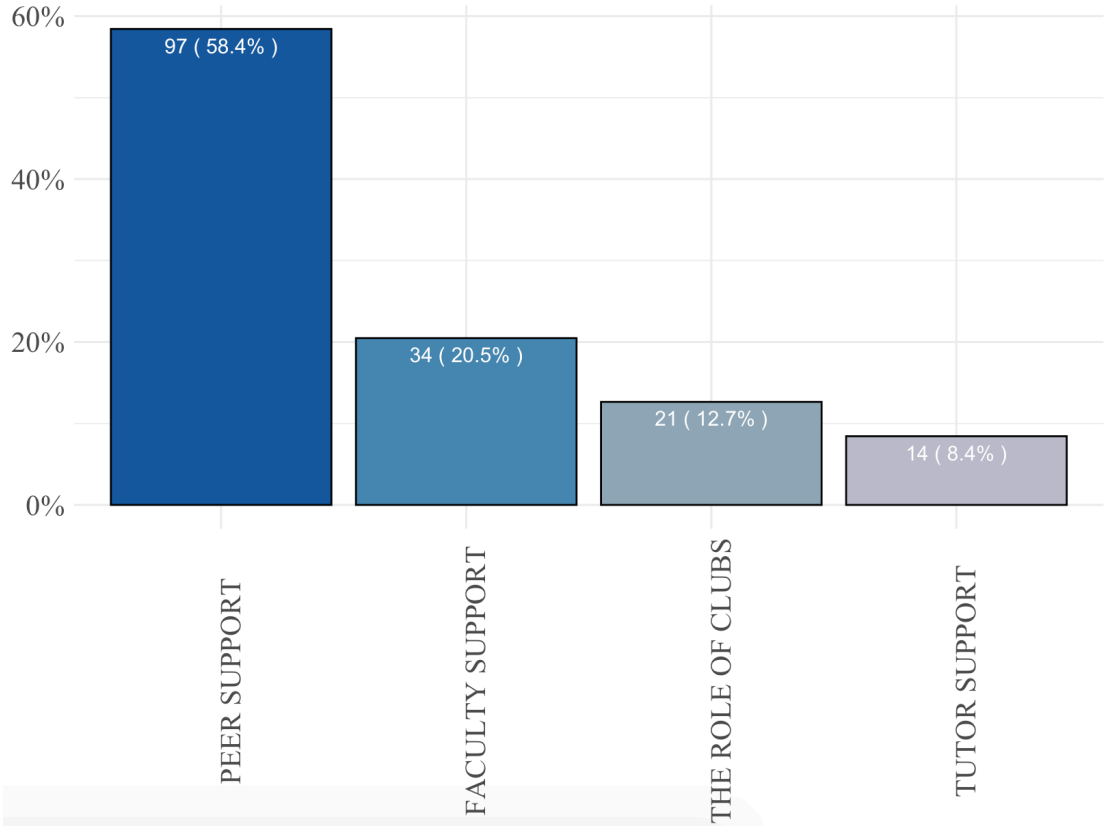


Table 10

Break-Down of Social Interactions by Gender

	Interactions with females		Interactions with males		Interactions with mixed or unspecified gender	
Social interaction type	*n*	%	*n*	%	*n*	%
Peer support	n = 12	12.37	n = 17	14.43	n = 68	70.20
Faculty support	n = 6	17.65	n = 11	32.35	n = 17	50.00
The role of clubs	n = 8	38.00	n = 1	4.76	n = 12	57.14
Tutor support	n = 2	14.30	n = 1	7.14	n = 11	78.57

Tutor Support

Tutor lab was a support group organized by the department, where senior CS students worked to help novice CS students with their homework and coding. As a resource, it was available to all the students every day of the week except Sundays (see Setting in Chapter III for a full description). The women described the lab as an "unstructured" type of support where you "could just go in and ask a question" any time you have a problem with any of your CS assignments.

For many women in the sample, the support of the tutors was "the only reason [they felt they] passed for the first year." In other words, while tutor support was not relevant to their experience later in the program, it was reported to be one of the most important support systems for their enculturation into the program. That is, tutor support was crucial for retention during the first few semesters in the CS major, exact number depending on the person. The extent to which these women used the tutor lab varied, but all women agreed that the tutors were a "good resource" which "help[ed] a lot" whenever they got "frustrated" or "confused" during the the period of initiation into the program.

The following testimony from Jane illustrates different ways in which tutors provided support.

> As a freshman or sophomore, I went to the tutor lab a lot, and so that's all just juniors and seniors helping you. That was huge for me. I wouldn't have made it through without the tutor lab. They are technical help, but also, their encouragement of like… "CS2 is hard for everyone. You're gonna get through it and it'll be okay after that." (Jane, interview)

From this excerpt, we can see that tutor support was crucial for Jane's success during the first and second year of college. Interestingly, in addition to the programming help she received, Jane also highly valued their encouragement and assurance that she was going to succeed in both the class in question, but also beyond. Many other women mentioned similar examples where tutors played a crucial role in their persistence.

The Role of Clubs

Several clubs and organizations also emerged as important for women's persistence in the major. Some of these clubs were located inside their CS department, such as ACM-W and Linux, while others were related to their university engagement, such as the University Ambassadors program, Honors Program and or the Outdoor Activities Program. Programs outside their department supported them in several different ways: by allowing them to have work-life balance, securing priority registration through the Honors Program, or providing them with financial support, networking opportunities and so on. As an example, two women worked for the University Ambassadors, which paid (part of) their tuition (i.e., it provided financial support) and created a lot of opportunities for their "professional growth," "networking" and or a "better perspective" of the field. All of these were experienced as important for their

overall satisfaction with the program and their motivation to continue studying.

Inside the major, several women felt that the Free Software and Linux Club represented somewhat of a gateway into the true CoP inside the major, where they could "improve their knowledge" while thinking about "different ideas, instead of just basic stuff." In other words, even though it was not required to know Linux, the knowledge of it helped them develop into more seasoned members of the community, while simultaneously getting more engaged with and invested into the major.

Four women also mentioned ACM-W, or as they colloquially referred to it "Women in CS Club," as important for their persistence. These women belonged to this club from the beginning of their studies. They found the club to be a "big support," as it was often equipping them with resources, some of which were based on discussions of how to survive within this male dominant environment.

> When I was like in Women in CS club… I remember we had this meeting and we were talking about [how] guys would say things…. to like sound cooler or smarter and really… it's like something super small, but they make it sound bigger, I guess. And that's… I've noticed that a lot in my classes, like … guys will say things and I am like "oh, wow! That sounds so smart!" and then later on, I'll find out what it is and I'm like "Meh!! I guess it's not that big of a deal!" (focus group one)

Joana shared this story in one of the focus groups. From it, we can see that gaining knowledge about typical behavior of men in this male dominant environment, which is documented in literature to intimidate women in their initial CS classes (see Chapter II), proved to be useful to Joana's persistence and self-esteem during her own classes. Instead of being intimidated by such incidents, she was able to acknowledge and demystify them along the way. Other women reported enjoying discussions about "different issues,"

interview skill nights, networking or having "somebody to talk to" as some other events they found beneficial within the club. Beatrice reported that her membership in the ACM-W club gave her access to the more experienced members of the community.

> I think [it] happened when I was first starting in the ACM-W club. There were quite a few women who were like a couple semesters ahead of me in classes, and so they were able to really help me out, and show me the ropes, and get me working through (…) There were a couple times where one of them, she was also a tutor, and so she was like, "Hey, if you still have problems with this tonight, just give me a call." So, I could call her and be like, "Hey, this is what's going on with my code.."… (Beatrice, interview)

In other words, by providing access to the more experienced women in the program, for Beatrice ACM-W served as another gateway to the much-needed academic support. Some of the other women used this resource as a way to get help with "really hard classes." Of note, no one talked about these women as role models, neither did they mention that it was important to have access to other women in the community.

Faculty Support

Faculty support was a consistent influence of women's retention in CS throughout their studies in this major. This type of support came from both male and female faculty, with support from female faculty being mentioned in 17.65% of cases (see Table 10). Overall, faculty support included both technical and emotional type of support.

> [This professor] is always great at… you know, being like, not only a support in school but you know, an emotional support, (…) she is always making sure that I'm ok, so that's helpful, a big thing for me. It's really helped me get through the major. (…) Not only do we work in research and she, you know, guides me through that… but every time I'm in her office, you know, talking about "here's the code," she is always like "ok. I appreciate that the code is going well! How is [sic] other parts of your life going? How is school?" and then we talk of things. So, she will always check on me. (Haley, interview)

As it can be seen from this excerpt, one of the professors that Haley worked for took special interest in Haley's life in addition to having a professional relationship with her. Receiving such emotional support helped Haley's retention in the major, as it gave her someone to talk to and confide in. Similar attention from faculty made other women in this study feel noticed, "comfortable" and "care[d]" about. The women particularly emphasized the importance of being noticed by the faculty (e.g., when faculty knew their name), but also reported that some faculty went an extra mile to ensure women's needs in the program had been met.

> I had one professor… there was […] someone in the class who said like a comment about like women versus men without like really thinking about it. It was just supposed to be a joke, but it could have definitely been taken as kind of offensive comment towards women and the next day he, the professor, emailed all the girls in his class, said he was really sorry, and he knew like…. It was hard to be a woman in CS and that he wanted us to know that we can reach out to him. Even outside his class, if we ever needed any support and [he] had this guy like apologize in front of the class. (focus group two)

As illustrated by this story, some faculty supported women in more ways than just academically or emotionally. This faculty member took the time to address sexism in class by personally apologizing to the women via email, acknowledging the challenges they faced in the major, and offering them support outside the scope of the class. In addition, he organized a public apology from the student who used sexist remarks in class. When discussing this incident in one of the focus groups, women agreed that it was events like these that were particularly important for how they felt about the program in general.

Apart from emotional support, faculty also supported women by providing academic or programming support through office hours and email. Some of the faculty

were seen as “master teachers,” who made CS classes interesting and contributed to their programming comprehension. Others provided good resources for learning and helped the women envision how they can succeed in the field. Women also found it helpful when professors acknowledged their feedback on how to redesign their classes so they were more accessible to those with no prior experience in programming.

Peer Support

The most prominent type of social support for all the participants in this study was Peer Support. Numerous examples of how women relied on their peers for educational and emotional support emerged from the data at different time points along their whole pathway of ongoing participation.

Peers serving as an educational resource that helped them “get through” their classes and assignments was one of the main reasons these women held peer support in high regard. I found examples of women forming study groups to go through class material and or “work[ing] together to solve a problem.” Women also learned by studying other students’ code, or getting feedback, advice and “hints” on their own code. They reached out to their peers with questions and received help with homework, classes and or class concepts. Sometimes they even worked next to or collaborated with older, more seasoned peers, learning from them or getting insights about the field and the type of expertise needed to succeed in it. Peers were also recognized to share helpful online resources with them, such as helpful tutorials and websites. When asked to talk about where she gets the right resources to persist in the program, Savannah emphasized the importance of her study group. These are the people she reached out to when she could

not find a book, could not understand a concept and or was “having a bug” in her programming assignments. Her study group was convenient and accessible, as they all lived close to each other or took the same classes. As a result, she would reach out to them on regular basis for any questions related to dysfunctional code, computing concepts and or resources she needed.

Another reason why women held peer support in high regard was the sense of belonging that they developed within their peer communities, as a result of being accepted and respected.

> I feel like I relate to the other students and that's my community. You know, I go to class every day with these students and sit in a classroom with these students. I do the same homework. I feel like I've always been able to make a group and form study groups. And if I go into a new class and there's a team project, I'm usually able to get along with the members of my team, like my ideas are heard and I hear their ideas, so I feel like—just all those little dynamics with my peers make me feel really included, and make me feel like happy to go and see them and joke around with them and make things with them and excited to work on the projects. (Savannah, interview)

Savannah here described how well integrated she felt within her community of peers inside the major. Not only was she taking classes and doing homework with them, they also accepted her friendship, respected her opinion and easily formed study groups with her. As a result, she enjoyed going to class and working on projects inside the major. Other women testified that similar feelings in relation to how many friends they had in the program helped them feel like they belonged in the program.

Finally, peers influenced women’s persistence in the major by providing emotional support. There were numerous examples of women reporting the importance of having someone to “sit with” in class, joke with, talk to about other aspects of life, such

as good companies to work for, or someone who encouraged them, validated their emotions and calmed them down when needed. In the following quote, Jane talked about the crucial role one of her friends played in her own retention in the program.

> One of my best friends is in CS with me and she is the only reason... Like we are each other's like the biggest reason that we got through it, I think. And we cry together all the time (laughs), yeah just like talking about "Yeah, it's hard!" and like, I don't know, talking about things that like motivate you (…) That's emotional support to me.(…) or like, a lot of times when we were first in the program, we had a couple like bad classes together and so just saying like "yeah, let's just talk to the professor!" and like "this is valid! That's a thing, it's good to be concerned about!" so just like somebody who like validates your views or… like really supportive. (focus group one)

This example illustrates the importance of peers' emotional support for retention of these women in CS. According to Jane, the peer that she talked about was "the biggest reason" she persisted as she had someone to share frustrations with, receive encouragement from, and vice versa. At this point, however, it is important to emphasize that only in about 12.37% of the interactions was the supportive peer specified to be a woman, while in the rest of the interactions the peer gender was either male or not specified (see Table 7 for more details). The data shows examples of both gender peers being important in the academic lives of these women with male support being more present due to predominantly male environment.

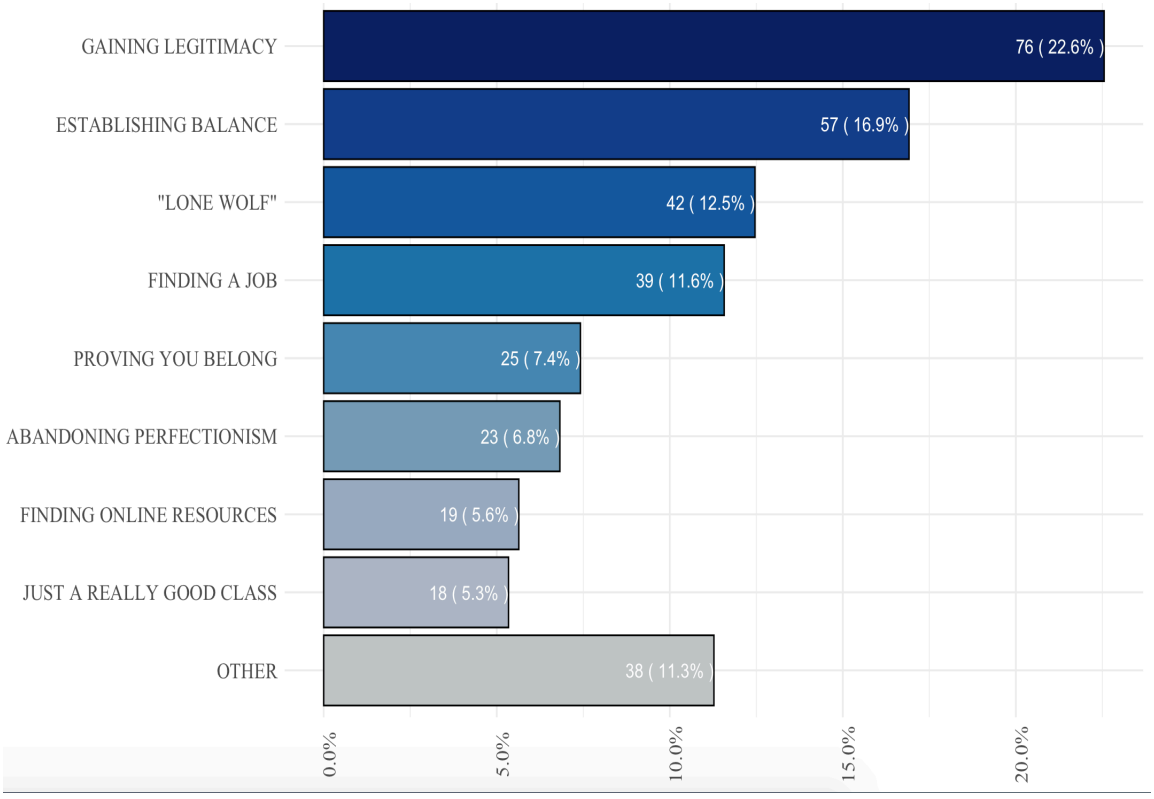
Practices Influencing Retention

In search of Practices that influenced retention of women in this study inside the major, nine different themes emerged from the data: *Gaining Legitimacy*, *Establishing Balance*, *"Lone Wolf," Finding a Job*, *Proving you Belong*, *Abandoning Perfectionism*, *Finding Online Resources*, *"Just a Really Good Class"* and Other (see Figure 3 for

frequencies with which codes appeared under each category). Figure 3 presents the frequency with which each of those codes emerged in the data. These themes will be described below in descending order from most to least frequent (with the exception of *Other,* which will be described at the end of this section). Of note here is the fact that in this study women were not found to learn solely within the CoP of their major. On contrary, learning happened at the intersection of three different CoPs (their major, their work and the online community of other CS professionals). Such multimembership (Lemke, 1997) framed four out of nine practices that influenced these women's retention in the major.

Figure 3

Frequencies of Codes for Practices that Enabled Participants' Retention (RQ1)



Gaining Legitimacy

Inside LPP within CoPs, legitimacy is defined as the act of acknowledging newcomers as competent members of the CoP and exposing them to authentic practices inside the CoP (Lave & Wenger, 1991; Wenger, 1998b). In this study, gaining legitimacy emerged as one of the crucial practices for retention of women in CS. In other words, women mentioned situations in which they felt acknowledged as crucial for their persistence with the major. Some of these acts of acknowledgement happened inside the major itself, and it came both from faculty and peers. The following excerpt describes one such act of acknowledgement, the way it was experienced by Savannah.

> A lot of students are just like, "Savannah knows the answer." I don't always know the answer and I'm like, whatever, but (…) It makes me feel good (…) that people see me as someone that they can ask questions to. I've had people ask me questions, like (…) "hey, I need help with this concept" (…). I'm a little bit of an authority and it just makes me feel like I belong; like my peers have recognized me as someone that they can go to. That—it makes me feel like I belong in the major. (Savannah, interview)

In this case, Savannah was legitimized by her male peers, other members of the CoP that she studied in, who perceived and publicly acknowledged her as a competent member, a person of "authority," someone who could give valuable advice and knowledgeable feedback. They did that by recommending her to other peers for advice and feedback. Other women mentioned being similarly "recognized" after winning hack-a-thons or other programming competitions, which caused their peers to address them more, congratulate them, or give them "hi-fives" in the hall, which in return made them feel "excited" and accomplished.

Another source of legitimacy, which was very important for their persistence in

the major, came from their work CoP. Bosses and co-workers acknowledging them as valuable members of the workforce, while at the same time exposing them to authentic practices, proved to be a huge source of confidence and sense of belonging in the major. The following quote from Shelby describes how that dynamic worked for her.

> I feel like [co-worker's name] helps me a lot, because he's super supportive. And he believes that I can do things. (…) For example, he just asked me to—write unit tests. I was kind of like, I have no idea what unit tests are. He kind of told me, "Well, just get started and we'll see how it goes." I don't know. That was kind of helpful to me, because it made me just jump in and try it. (…) Just his faith in me helps me believe in myself, 'cuz he's kind of like, "Oh, you're a programmer. You'll know how to do this." And then obviously if I have questions, or if I get stuck, he's very willing to help me figure it out. (Shelby, interview)

Getting acknowledged at work as a programmer who knew how to problem-solve, while at the same time receiving support when support was needed, was very important for Shelby because it allowed her to approach her work with confidence, while at the same time being comfortable with asking for help. Other women in the study reported that legitimacy received at work was influential on their sense of self, because it made them feel "capable" and able to succeed in both their major and at work. Getting a job offer, a summer job (which they sometimes referred to as internship), or an offer to stay at the company also identified as important sources of legitimacy that originated at work.

Interestingly, gaining legitimacy was perceived as a bidirectional practice. While acknowledgement from other community members (internal and external to the major) was very important for their ongoing participation in the major, it was also important to get legitimacy from within themselves. What this means is that some women felt that receiving legitimacy from co-workers and or peers and faculty was not always enough for them to feel competent. They felt that for their feeling of competency to be sustainable,

they also needed to acknowledge themselves as valuable and competent. This, however, was not an easily reached point especially when considering their proclivity to perfectionism described below. The following excerpt from focus group one illustrates the bidirectionality of legitimacy.

> If I think I did a good job, then that's [more] meaningful to me than like a professor saying "oh! You did a good job!" 'cause they don't really know me. Like, they know like one set of code I wrote for them one week, so I think like when I feel like I did a good job or when I feel like I belong that's the most powerful. Just knowing that I gave my best, not thinking like "oh, I could have spent more time on that!." Just knowing "oh, that was the best work I could have done on that time!" (focus group one)

In other words, Jane was her own worst critic. Even if she received acknowledgement from a professor, she did not find that type of validation to be as meaningful as when she herself was pleased with her own performance. Similarly, other women felt their legitimacy was confirmed when they felt they "got a good grasp" and "understanding" of the matter, they "ma[d]e it through classes" and or they themselves "felt good about" their progress regardless of whether or not they received "validation" from others. One common strategy they used to feel good about their competence in the subject matter was to provide help to others.

> My friend [name] and I, she's a physics major and I'm CS (…) Helping her is really nice, because I'm like "Oh yeah, I remember useful things." I feel like that's a theme, but just whenever I'm able to teach other people, then I'm reminded that I know things that other people don't know, and I can help them because of that. So anytime I get to teach, I think that helps remind me. (Jane, interview)

As it can be seen from this quote from Jane's interview, helping others served as a reminder of her own competence and knowledgeability. Helping others also helped her realize that she had moved away from the periphery of the CoP and became a more

experienced member of the community, one who can now give back to the community and support others. As a matter of fact, Jane and some other women consciously invested time trying to make "the experience better for other people," as they found it "fulfilling" and it gave them a sense of "doing well" in the program. Some even mentioned that "teaching and helping others" was good as it helped them learn even more.

Establishing Balance

Most women in this sample reported having a hard first semester or year in their CS major. Apart from Haley and Savannah, who came to the major with some programming experience, and Maggie who was an experienced university student with two majors under her belt, the rest of the women in this study described their initiation into the program as a "blur," "devastation" or a very "rough patch" where they had to work a lot to maintain good grades. Whether immediately or gradually, most women adopted some type of practice that would allow them to establish (or restore) the life-work balance in their daily lives, which consequently, contributed to their persistence in the major. There are several ways in how they achieved that balance.

A few women had a minor in a CS-unrelated field, such as German, Business, American Sign Language (ASL) or Psychology. As an example, Shelby felt her German classes were "kind of like a break" from all the "difficult" CS classes, as they were "fun" and not as demanding in terms of homework. For Erin, classes in another major (ASL), which was predominantly female, provided a vehicle for finding more female friends, which, as she put it, helped her "even [herself] out" and not be overwhelmed by her male-dominant CS major. Jane, on the other hand, balanced her CS workload with some

Business classes.

> The next semester… (…) I just took four classes, which was a lot easier and two of them were in business, which I'm naturally a lot better at, and so that was the semester that things like really started looking up finally. (Jane, interview)

In other words, the balance of CS and Business classes helped Jane feel less overwhelmed with her major. As it will be shown in her case study later in this chapter, Jane's enculturation into the CS program was difficult. She struggled to pass her CS classes and earn good grades. On the other hand, she performed well in her Business classes. Even though, according to her, she took Business classes as an exit strategy from CS, those classes ended up providing the necessary balance for her to persist in the CS major. The business classes provided her with a necessary balance in the type of workload that she had.

Another strategy these women used that helped them establish work-life balance, was to consciously reserve time for other things in life, such as religion, sport, family time or "down time." For instance, Monika talked about a balance of physical, social, and spiritual needs being met in addition to "computer science stuff" as crucial to her persistence in the major. Beatrice talked about the importance of "moderation" for her motivation to continue participating in her major, as she had periods where she would "go to extreme" with working on her CS assignments, which would cause her to "burn out" and lose motivation to study. To explain how she succeeded in the program, Adele said:

> I kind of try to balance my life. So, things like my major can progress (…) A physical balance or be physically active. And an academic balance, so do well on homework and a spiritual balance, so kind of focus on my church, as well. And I find that, if I kinda have the balance with my body as well as my mind, then I can

> succeed in what I wanna succeed in, so computer science. (…) ‘cause sometimes I find myself overwhelmed, but I try to kinda re-center myself into balance, ‘cause sometimes if you lean too much into academics then you don’t really get physical exercise which can release stress. (Adele, follow-up interview)

As an avid basketball player and someone to whom church was important, Adele believed in the triad of mind, body and spirit to be the foundation of her persistence in the program. Being able to release stress through spiritual and physical activities whenever she was overwhelmed with CS homework was one of the most important aspects of such balance for her. Many women also talked about relying on “scheduling” fun activities, “free time” or “down time” in addition to homework and study time, so they made sure they achieved life-work balance. Whether their idea of relaxation is “working out,” “watching Netflix” or “socializing,” these moments were reported as important for their retention because, according to them, it helped them “get [their] mind off of” CS and or “get out of [their] head.” Additionally, it helped them “destress” by engaging with something that “does not require brain power” or serves as “an alternative problem” to solve. As a result, they felt that “down time” increased their productivity in the long run.

“Lone Wolf”

In her attempt to explain how she approached learning and studying, Adele said: “I do a lot of my studying on my own. I’m kind of a lone wolf in that way.” A similar explanation was used by many of the women in this study in reference to their approach to learning CS. They would describe themselves as someone who “do[es]n’t do a lot of people,” is “very self-sufficient,” “self-learning,” “self-teaching” and or “independent.” To explain the rationale behind her independent approach to learning, Adele said:

> I get distracted with other people there, or they don't really go over what I need. (…) I've always been an independent person. I like to figure it out myself. I feel like it takes away from my learning if I get too much help from other people. (Adele, interview)

This idea that group work could take away from the learning experience is one of the reasons seven of these women preferred "self-learning" to learning in study groups. Other women mentioned being "excited about figuring stuff on [their] own" and or finding learning more gratifying that way. However, even though the "lone wolf" approach was the most popular approach to learning, it did not exist in absolute isolation from other practices important for persistence. In particular, such approach did not exclude the need for social support. This is illustrated in the following quote from Joana.

> I do have a few people that (…) I try to be friends with (…), but I don't depend on them, because I've tried that, like … working always at the same group and getting through a class together and I feel like that's not for me. Mostly because I like to figure out the solutions by myself and… (…). Like sometimes I just get stuck on some point in the semester, I get stuck and I feel like I have a few friends that I can reach out for and be like "oh! Can I work with you guys?" (…), but it never helps in the long-term, I feel like. So, if I have a hard week or it's like a lot of homework and I don't have a lot of time to think about a problem, then I would go to these resources, but I just like to think through the problem by myself, so…(…) I feel like I learn more for sure. (Joana, interview)

As we can see from this excerpt, Joana, like Adele, believed she "learn[ed] more" when she worked independently on figuring out the problems in her assignments. However, whenever she did not have enough time to work on a problem or the amount of homework was overwhelming, she still used available social support, more specifically peer support, to succeed in her major. This was true for most women who identified the "lone wolf" approach to be their approach to progressing through their major.

Finding a Job

According to Google dictionary, a job is a paid (part-time or full-time) position, while an internship is the position of a student who temporarily works in an organization, sometimes without pay, to satisfy requirements for a qualification. Based on personal communication with one of the faculty members in CS department at this university, I found that internships were not required by this CS program. For that reason and the fact that they were always paid, all the positions that they held during their CS studies will be referred to as a "job" in this study.

Most women found a job early in the program, which most frequently started as a summer job and often turned into a part-time job for the duration of their studies. According to them, this practice played a major role in them "sticking with the program." One of the reasons behind the importance of this practice was that it gave them an opportunity to gather explicit knowledge about the field (versus a more tacit and fragmented knowledge that they got inside the major). In her interview, Maggie explained how and why the learning experience in her first job was different from her learning in school.

> A lot of the first little bit was just completely reading code, and figuring out what is going on, because I'd never seen a program longer than a hundred lines of code, and now I'm looking at thousands, and thousands, and thousands, all merged together, in one huge project. So, spent awhile just wrapping my mind around that, of how much can go into one program. A lot of words, I did not understand in the code…like 90% of what was said went over my head. So, there was a few meetings I had, just one-on-one with my hiring manager that I literally just asked him vocabulary questions.… But, there were things like…I had to learn a new programming language, and a different operating system.… So I don't know… I think there was just a lot of different varieties of learning, and I think that's why I enjoyed it so much is because I wasn't just learning one track the whole time. I was learning all sorts of different new skill sets. (Maggie, interview)

In other words, getting a job not only gave Maggie a chance to learn new skills, but she was also learning meaningful things, as she was exposed to authentic learning opportunities from day one. She was able to see how code looked like in the "real world," study the code, talk about the code and build on it. Other women also reported learning and growing "a lot" in their jobs, sometimes even taking "control of [their own] learning" by instigating projects of their own interest and or connecting them to school projects, which in return enhanced their learning inside the major. As an example, Haley proposed a redesign on a software package they used at work to enter data, as she experienced it as "clunky." Her redesign immediately "graduated" her from her entry level job to the development team, where she experienced a steep learning curve, learning four or five programming languages in two months. Women who were exposed to this practice felt that the explicit knowledge gathered at work, or "hands-on" knowledge as some women referred to it, gave them an advantage in school in terms of performance, competence and or organization of tasks.

Finding a job also had the benefit of helping women experience and envision what CS was and what it would be like working in CS industry. Whether it helped them "figure out what environment" was best for them, or if CS would allow them to realize other things that they were passionate about (e.g., "make a bigger difference" in the world), such moments were often reported as crucial to their persistence in this major.

> I think [it was] probably the project that I did that I talked about that kind of lead to my first decision to stay in the major – the project that I did at work that I got to be the team leader for, because I think that showed me – that was the first time that I really saw that being a programmer meant more for me than just getting to program, but it meant that I would have leadership opportunities and opportunities to communicate with people and like… It broadened my perspective of what it

means to actually be a computer scientist. (Monica, interview)

Here we see Monica explaining how one of her first work projects influenced her retention in CS by broadening her understanding of the CS profession. Most importantly, she was able to realize which aspects of a job (e.g., leadership, communication) were both important and attainable inside the CS industry. Other women reported liking the "social" aspect of their job, the "welcoming" environment, and the feeling of being "included." This provided a welcoming contrast with situations inside their major where they occasionally felt like a minority due to a large number of men.

Proving you Belong

Another practice that many women adopted while engaging in their major, which helped them persist, was to prove they belonged inside the CS community. Similar to gaining legitimacy, the act of proving they belonged was directed both towards themselves and the community. However, these efforts did not necessarily align with getting and or feeling legitimacy. Among other things, this practice was realized by outperforming others (i.e., men) with hard work and better grades, and or by confronting anyone who doubted their success and or ability to do CS.

According to Monica, the "pressure to be the best" and outperform men felt strongest in classes that were not her "strength." Similar feelings motivated many of the women to "work harder," "learn more," "dig deeper" and or "study harder" so they could "get to the same point" as the men in their class. As an example, Maggie mentioned a "passive aggressive" strategy she used to prove herself to her peers.

If I really feel like there is a really hard problem that I can solve and if I can come

> to the board to solve it, I'll go… and so I am like "Yeah, I am a girl, but I can do this!" You guys probably couldn't [Everyone laughs]. (focus group two)

In her opinion, this passive aggressive approach allowed her to shine in front of anyone who might have had any doubts about her competence, due to which she carefully chose situations that would work to her advantage. Efforts to prove themselves with hard work also included working on "get[ting] better grades" than the rest of the class and or working on "get[ting] all As." Another strategy they used to prove they belonged was to openly confront anyone who doubted them and or their right to be part of the program.

> I never let anything go, I always attack that. Dead on. I am just like "Hey, that's inappropriate and I am smarter than you are, so that's why I got the interview!" [laughs] that's not… like I don't like it when people say [I got a job because I am a girl] 'cause that's like… all of your hard work is like marginalized to just your gender like…. The thing you didn't even choose. (focus group one)

Though examples of marginalization were not reported frequently in this sample, it was interesting that it inspired some women to react more aggressively, such as with open confrontation, while others used more passive aggressive approaches to prove themselves to the community, but also to prove to themselves that they belonged in CS as a major, despite being in smaller numbers in all of their CS classes.

Abandoning Perfectionism

For most women in my sample, one of the biggest milestones in persisting with their CS major was accepting that you do not have to be perfect in everything inside your major. Considering that most of them came to the major as really good students, moments when they were not able to complete an assignment were also moments when they most frequently thought about "quitting." In addition, entering a male-dominant field where a

lot of students had significant prior experience with programing was a struggle.

> We all struggle a little bit with that perfectionism, with that feeling of "we already have to be there," "we already have to be at this and such level," "we already have to be doing this well," and I feel like it can be really hard to be patient with yourself, especially if we feel like we have to prove ourselves, it can be hard to just say "I don't have to prove to them that I am already perfect! I just have to prove that I am willing to keep going and to keep trying and to keep working!" (focus group 2)

In other words, in the second focus group, the women agreed that the struggle with perfectionism was something they all had in common, as they all occasionally felt they needed to "prove" themselves by "doing well" and being at a certain (usually high) level of programming. Abandoning perfectionism was a practice that was hard to adopt, but they all admitted that once they managed to let go of their imagined ideal self, they actually developed a stronger sense of belonging to the program. As an example, Shelby talked about getting a B in Physics, which ruined her "perfect" 4.0 GPA. For her, getting a B was liberating as it put things into perspective in terms of what mattered and what did not "really matter anymore." Another example is provided by Jane, who talked about the significance of allowing herself to withdraw from a class, even though it was "too late" in the semester.

> That was actually a high point because I finally felt like even if I drop a class, I'm still a computer scientist. Just because I don't really like JavaScript doesn't lessen my ability in C ++ or other languages. I was finally able to cut myself a little bit of slack and just be like "It's okay that I'm not good at every language." Like its fine to let go of something. I don't have to be the best in every single way. (Jane, interview)

As we can see from this excerpt, abandoning perfectionism in order to persist in the major was connected to deeper understanding of what it meant to be an expert in CS. The women reported realizing that CS was a "skill based" field with a "bunch of different

languages," where "everyone [was] constantly learning new skills" and no one really knew or needed to know everything to be an expert (Haley, focus group). Comparing oneself to more knowledgeable and experienced members of the community, therefore, was counterproductive, as "you [could]n't be good at everything." What you could do, according to them, was develop expertise in a few CS "aspects" of your own and realize that a "different background" did not disqualify you from the profession. To be able to abandon perfectionism, women used a couple of different strategies. One of the strategies was to give themselves time to learn a new skill, as mentioned in the following excerpt.

> To persist you just need to be patient with yourself and give yourself the time to figure it out. I feel like that's something that… when I struggle the most, are the times when I am not patient with myself, when I expect myself to already know the answers, to already have an understanding, to figure it out immediately, and when I take the time to say "it's ok!" Like "give yourself time to learn how to do this! This is completely new." (focus group two)

In this focus group, as illustrated by the quote above, women talked about the importance of patience for their own retention in the program. Practicing patience with self was not easy and it took them time to accept that learning took time, especially when developing a new skill. Once they accepted that and started practicing patience, it was easier for them to develop a sense of belonging in the program.

Another strategy that women used to abandon perfectionism was to admit that they occasionally needed to ask for help.

> Once I was on… (…) this group project that I was doing (…) um, I wasn't asking how to do it. I wasn't asking for help, and one of the guys figured it out and he like sat me down and he was like "Look! It's ok if you don't know how to do it. I don't care if you don't know how to do it, but you can't just struggle by yourself. Sometimes you have to just like actually ask someone and that's ok." And so, I guess I had to learn when it was the right time for me to have to actually go to someone and admit that I don't know how to do it. Because you know… I wanted

everyone to think that I knew what I was doing… (Shelby, interview)

Perfectionism was part of preserving a certain impeccable image, as we can see from this testimony from Shelby. Once a peer instructed her that asking for help was a more acceptable practice than "struggle[ing] by yourself," she realized the pressure she felt to be perfect in front of her peers was both unnecessary and non-productive. As a result, she accepted the new reality in which admitting you did not know everything and asking for help was a normal part of the learning process.

Finding Online Resources

Another practice that emerged as important for their persistence is their developed ability to locate, evaluate and utilize online resources. This practice requires a high degree of skill to master. In both focus groups, women agreed that developing such skill was one of the most important practices for ongoing participation in the program, one that was neither overt inside the CoP nor specifically taught. Though no one mentioned what it took to acquire such skill, all women reported relying on the Internet to find answers, do research and reach out to online programming communities, such as the Stack Overflow community, which is an online community of programmers. The following discussion happened during one of the focus groups when the women were asked what people needed to succeed in their major.

Maggie:	Learn how to Google the right questions. [laughs]
Beatrice:	Yeah, learn how to Google is a big one because a lot of times people would Google really badly.
Monica:	Yeah (…)
Interviewer:	Ok, can you tell me more?

Savannah: Certain key words!!

Maggie: …like when they get certain errors like throwing in specific names for the errors and that sort of thing where like… that's something you wrote exactly and so it's not gonna match word for word with someone else 'cause if it's like your variable and something like that… so you gotta extract what's from … what's your error part and what's like the global error part, so then you Google the global one.

Everyone: Yeah! (focus group two)

In other words, according to these women, the practice of finding resources online is one of the most important practices inside the CoP of their major. To practice it, one needs to develop it as a skill, which, as we can see from the excerpt above, is not easy. If you conduct good Internet searches, they said, you get the right educational support for your assignments. If you "google badly," the Internet, which is full of resources, is of no use to you. Both these extremes were reflected in the data. On one hand, women mentioned examples of them not being able to find the right answers on the Internet in the beginning of their program despite numerous attempts to do so. On the other hand, there were numerous examples of them relying on the Internet regularly later down the road. For some, this skill translated into learning how to "ask the right questions" in general, both online and in person, which was "a major skill that the major refined for" them. Others called themselves "stackoverflow-sufficient," especially in their upper level classes (Note: Stack Overflow is an open online community for people who code), which basically meant that they combined their "lone wolf" approach to studying and doing homework with the support they got from online communities for people who code, such as Stack Overflow.

"Just a Really Good Class"

In most participants' journeys, a college-level class that they took while completing their CS major emerged as pivotal at one point of their college education. While this theme did not permeate their experience throughout, it still appeared in most woman's stories at least once as important for their retention in the program. The ways in which classes influenced women's persistence were multifaceted and they ranged from helping women gain confidence in their CS competence to helping them visualize "how it'll be in an actual job" in the industry. As an example, some women reported that certain classes served as good platforms for their skill acquisition and or provided moments of clarity on their way to gaining competency in the field.

> I do remember having a whoa! moment in CS2 where I was like… wasn't lost anymore, 'cause I always wanted to do this one thing in CS1 and all the programs that I wrote and then I am like "if only there was a way to do this!" (…) and then in CS2, they teach you this thing (…) and then I was like: that's all I ever wanted to do!" (laughs), this whole time!! So, that was like my: Wow! I am not lost anymore! moment kinda thing. (Joana, interview)

Like many other women in this study, Joana had a rough introduction to her program. She was overwhelmed by the new concepts and terminology in the major, as she had no prior experience in it. As we can see from the excerpt above, such situation contributed to her feeling "lost" in her classes and not always being sure how to solve a programming challenge in the best and or most efficient way possible. CS2 class, however, provided her with some inspiring "aha" moments where she learned the things she needed, and consequently, gained clarity in the subject matter. Similar examples included women mentioning classes that had a "huge learning curve," classes where they learned "something different" and "very useful," or classes that were simply "cool," such as the

Women in Engineering class, which served as a support in their persistence. Some felt that "everything else buil[t] from" such classes, while others considered such classes to contribute to them being a "little bit more in love" with CS. In some of those classes, these women reported learning the necessary "technical skills," while in others they learned how to think through problems, both of which they considered to be important for their future careers in CS. Another important role some of these classes played in their retention was to help them develop confidence in their ability to succeed in the CS field.

> …that was just a really good class. It was just—it made sense. Like the effort I put in was rewarded equally, and that had never happened before. If you studied in his class, you did well and you got an A, and if you worked hard, it was rewarded, and other people didn't know more than you just because they already did. It was finally equal footing it felt like, so that was really good. (Jane, interview)

As we can see from this example, taking a well-designed class that was inclusive of people with no prior programming experience was crucial to Jane's self-efficacy beliefs. In this class, she felt like she was on "equal footing" with her classmates, as the only criterion for success was hard work. Having an experience like that helped her realize that she could "learn new concepts" and she had the ability to succeed in this major.

Last, some classes were reported as important for their retention because they were illustrative of what it would be like to work in the CS industry. Some examples include seeing "how a bigger company would" deal with project management, "what it was like working with people" or how to work off of someone else's code, all of which contributed to women maintaining their interest in the major and persisting with it.

Other

This category includes all the factors that influenced women's retention in this major that could not be categorized in any of the other categories. Some of the reasons that made them uncategorizable were the fact that they emerged only a few times (e.g., belief that CS is more flexible and or mommy-friendly than some other majors; focusing on near graduation), and or they were relevant for one or two participants alone (e.g., faith in God, seeing how CS can support one's preferred lifestyle, attending an event which supported their retention) and so on.

Communities Women Belong to Outside of their Major

Research Question Two was designed to unearth additional communities, apart from the communities inside their major, to which women belonged as they worked towards the completion of their degree. For most women learning was a matter of multimembership in different CoPs, as it can be seen from the following example.

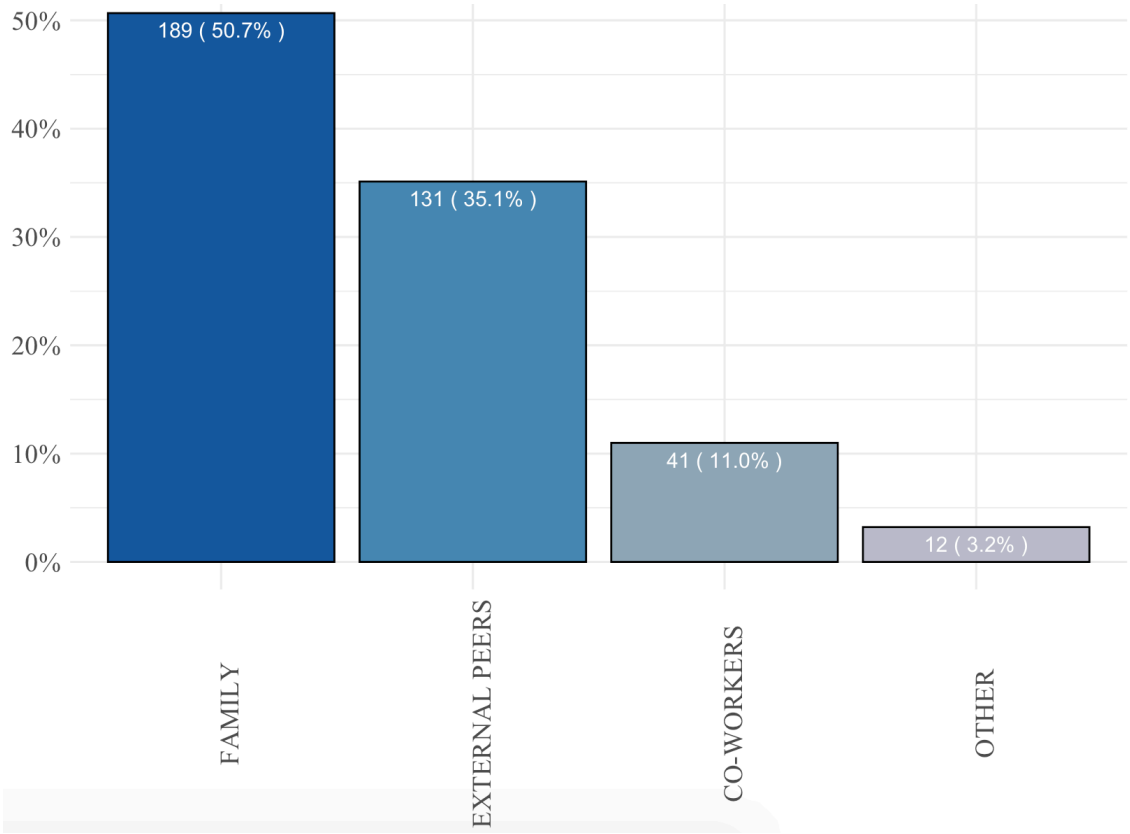
> The CS community that I want to belong to and I feel in large part that I do belong to right now is a mixture, having like at least some professors, some professionals that I know or can talk to and some other students, 'cause I feel like that mixture gives you like…. Professors that you can go to with questions, like really hard questions. Or professionals who can help you with like job aspirations and ideas and then students who are like on your level and they can help you with like the classes that you are in together, they can help you feel welcome and accepted in activities and classes. (Savannah, interview)

According to this woman, her "CS community" consisted of both people from within the major and those from the outside. These included other students and professors, but also professionals that they connected or worked with. Upon analyzing the data, three external groups of people emerged as the most important communities for the women in this

sample: *External Peers, Family,* and *Co-workers.* See Figure 4 for frequencies with which these categories have been mentioned across all data sources Several other communities, such as their church community, the online/outside CS community and so on, were mentioned a few times and were categorized as *Other*.

Figure 4

External Communities Participants' Belong to (RQ2)



External Peers

Community of external peers, or peers that did not belong to the same major, was one such community that women reported belonging to. These consisted of two different groups of people: their roommates and friends from other aspects of their lives. Both

roommates and external friends emerged mostly in their daily routine through the ESM data as someone that they spent 19% of "waking hours" with (see Figure H3 in Appendix H). While external peers were never reported to provide academic support, their emotional support was equally important for these women's persitence. In her interview, for example, Adele explained how important her roommates' support was to her.

> I'm with [my roommates] most of the time, so I think, when I'm like complaining about an assignment, or trying to figure it out, they're like, "Well, I have no idea what that is, so at least you know what you're doing." I'm like, "Well, yeah, that's encouraging." So, or when they ask me for any technological help, even if it's really simple, and they're just havin' a rough day. (Adele, interview)

In other words, Adele's roommates were a community she belonged to outside her major that served as important support for her during her CS studies. They were both encouraging her when she was having a hard time with homework, and their reliance of her help with their own "technological" challenges, no matter how small they might have been, helped her believe in her own competence in this subject matter.

Family

Another community that women in this study felt they belonged to was their family. The biggest subcategory here was their partner (husband or boyfriend). Two of the women had a husband and three had a boyfriend that they spent a lot of time with. Their role in these women's persistence was mostly based on providing emotional support, while at the same time taking care of them in other ways.

> I feel like having a spouse is such a support in so many ways. Like it relieves stress in other ways, too, because I'm no longer in charge of doing all my own laundry and cooking all of my own meals and cleaning the apartment by myself. I have someone to help me even just with the little household chores. So when I'm working on a program, and I'm, like, I need to get this done. I don't have time to

> make dinner, he makes dinner, and it's fine. (Monica, interview)

From this excerpt from Monica's interview, we can see that having a husband helped her aleviate the stress of everyday life, as he was someone who took care of her and helped her when she was overwhelmed with homework. Other women reported receiving emotional support and encouragement from their partners. Another subgroup inside the family community were their parents. Parents were reported to provide emotional and occasionally, financial support, to these women throughout their studies. Moms were usually described as someone who checked in with them on their progress, talked to them when they were struggling and provided encouragement. Some fathers, on the other hand, emerged as brokers (Wenger, 1998b) helping the women make connections with the CS community in general. They also sometimes helped them bridge different CoPs included in or necessary for their education.

> I went back home, and I was home for a little bit and I was looking for jobs and just couldn't find anything. My dad, he works for a tech company and he didn't want to hire me because the boss is kind of mean. (…). After a couple of weeks my dad realized that I wasn't gona find another job, so he offered me a job as an intern. (Shelby, interview)

In this example, Shelby explained how her father stepped in when she was struggling to find an internship. By brokering an internship for her in his own company, he secured a practical experience for her that not only helped her financially, but proved to be crucial in her education, as it helped her build on the tacit knowledge she gathered in the major, as you will later see in her case study. Another way fathers brokered their daughters' involvement into CS was to encourage their choice of major from early age, by telling them "[they] can do whatever [they] want[ed]," and or by giving them resources for

learning CS at a young age. Some father also helped their daughters with homework and or talked them through coding problems.

Co-Workers

Finally, the community of people the women worked with also emerged as an important community for them, as most were actively working at the time of the interview. These included some people who belonged to the same major as they, but whom they did not know from school, as they were mostly older. The majority, however, were no longer in college. From my analysis of practices that influenced women's persistence in CS, we learned that work was one place where these women received legitimacy, while co-workers helped them develop a sense of belonging to the field, among other things. Additionally, as earlier discussed (see *Finding a Job*), work was an important source of practical learning opportunities, while finding and or having a job served as an important practice for their persistence.

Other

A lot of women had another community or two that they felt they belonged to, but these were not consistent across the sample. Some of these included different communities inside the university but outside their major, church communities, volunteering communities and similar.

Participant Stories: Individual Pathways of Participation

Research question three investigates individual pathways of persisting women's

ongoing participation in their CS major. In other words, it seeks to illustrate what a journey of ongoing participation typically looks like for women in CS. In this section, I present a cross-case study analysis of all ten participants, where the goal was to provide an outline of pathways throughout the major that a woman who persisted in CS typically embarked on. The case-study analysis is followed by 5 (out of 10) richest and most diverse case studies that describe five distinct personal histories of retention (for the remaining five case studies see Appendix I).

Pathways of Ongoing Participation:
A Cross-Case Study Analysis

One of the goals of this dissertation is to understand the journeys that the women in my sample embarked on and whether there were patterns and similarities across these different journeys. Unlike what we see in other studies using journey maps (e.g., Meyer & Marx, 2014; Nyquist et al., 1999), half of the women in this study framed their journey using a mathematical and or a scientific concept, such as a chart, graph, algorithm and or a function. One potential reason for such visualization may be found in Adele's interview, where she said that she had a "math brain" which made her think in graphs and timelines – a thought that was reflected in other women's explanations as well. I found these representations interesting, as they represent a somewhat unique insight into how CS women may think. The following section illustrates some of the commonalities and differences along these different pathways.

The women in this study worked on their CS degree in Intermountain West region of the US. On average, they were in their twenties, and had a part-time job in CS (see

Table 3 for more details on the whole sample). Contrary to what might be expected, they rarely had any experience with programming prior to becoming a university student. As a matter of fact, seven out of the ten participants in this study took their first CS course in college. Some of them, however, did have a father who was directly or indirectly engaged with programming and who supported their college experience in one way or the other. For example, Savannah's father introduced her to coding, Shelby's father consciously built her career self-efficacy and helped her find her first CS internship, while Erin's and Monica's fathers, both of whom were programmers, served as emotional and educational support throughout their studies (for more detail, see RQ2).

The women's motivation to study CS varied widely across different cases. One woman was motivated by a CS scholarship despite being interested in another major, one was persuaded by a friend, and one wanted a "viable" major that could help her maintain the lifestyle that she was accustomed to. Of those who started in a different major, one woman got introduced to programming at work, one got excited about computing during her leave of absence, while one switched to CS in search of a more "mommy friendly" career. Interestingly, three of the women stumbled upon CS classes by accident, while trying to satisfy a requirement for their declared major. That first class then sparked their further interest in CS.

As hinted in the previous paragraph, typical entry into the program also differed widely across different cases. Some women entered the program at the very beginning of their university studies, while others transferred from other programs or came from another institution altogether. The exact moment of transfer also ranged from as early as

first semester to several different points down the academic journey. For example, of all the women in this study, four declared CS as their major from the beginning, three switched to CS from different engineering majors, one triple majored in CS, Math and Physics, one switched to CS after trying several different majors and one remained Undeclared for as long as she could to make sure CS was a good choice for her. If a novice woman declared CS as her major from the beginning, she was equally likely to have most of her "generals," which refers to the core or basic college courses, finished in high school, as she was to come with no generals. The phenomena of being able to "stumble upon" CS classes as well as being able to enter the major at different points in time, however, testifies to the porous nature of the boundaries of CS major, which I will discuss more in Chapter V.

Typically, most women in my sample experienced the first couple of semesters as "rough" and "overwhelming" due to an abundance of new terminology and concepts in introductory CS classes. In this study, I found evidence of their initiation into the CoP of their major being exacerbated by her own *perfectionism* (e.g., desire to have all A's), determination to *prove they belonged* in this major, and lack of skill in finding online resources (for more detail on these practices see Results for RQ1). Such initiation period was even harder for women who completed their "generals" (either in high school or in another major), as they were exposed to an all-CS class schedule, with little to no room left for a balance of CS and non-CS classes. In other words, no additional support was provided for these types of students, even though enrollment with such background was allowed. If there is room left for some general courses, the woman sometimes chose a

minor in a non-CS related field, such as German, Business, Phycology, or American Sign Language.

One support system that was organized for all the students entering the program, which can be construed as the periphery of the CoP, was the Tutor Lab. At one point early in their program, women usually started reaching out to the tutors for help. Run by senior CS students, Tutor Lab was identified as one of the crucial resources for these women's retention in those early days. Another resource organized specifically for the support of women in the department, the ACM-W club, was also attended by some of the women, but not all. This resource allowed them to meet other women in the program, gain more academic support and learn about some typical copying strategies for studying in male-dominant environments.

After taking only a few CS courses, most woman were able to find a summer job or a CS-related part-time job (e.g., Teaching Assistant for one of the introductory CS courses). This first job was beneficial for their retention, as it gave them explicit experience through authentic learning opportunities and opportunities to receive acknowledgement from their co-workers. Additionally, they reported gaining broader understanding of what it is like to work in CS industry and developed a belief that they can succeed in it (see RQ1 for more detail on *Finding a Job*). Sometimes women kept the job (part-time) after going back to college, and or the job inspired them to find another one closer to home. No one reported a negative first experience at work, and eight out of the ten women I interviewed had a CS-related job at the time of the interview, even though they were all full-time students.

Upon returning to college after their first summer job experience, women would often move away from the periphery of the CS CoP by becoming more engaged as active members inside the CoP of their major. In this study, we see examples of women regularly reaching out to the professors and or peers for help, but also giving back to the community by coaching and mentoring others. Even though most of them reported having an individualistic approach to learning (see *"Lone Wolf"* section in RQ1 results), peer and faculty support remained an integral part of their learning experience, as well. The extent of such support depended on the person and it ranged from having a few study buddies (e.g., Shelby or Erin) and or asking the "person next to you" for help (e.g., Maggie, Haley and Joana) to having elaborate study groups and or taking classes with the same people (e.g., Jane, Savannah or Monica). At this point, women reported gaining enough competence in both the subject matter and finding resources online to start believing in their own competence. Therefore, they often abandoned striving for perfectionism as a practice and worked actively on establishing their work-life balance. The balance was sometimes introduced via religious and or sports activities, and or it reflected in designating some "down time" for relaxation and or socializing.

As it can be seen from this cross-case study narrative, women's individual journeys towards completion of this major have some commonalities, such as the challenge of initial enculturation, as well as which support systems they had and practices they adopted along the way to support their own learning and retention. However, those same pathways of ongoing participation also differed in many ways, from how they entered the program to what combination of support worked for them specifically. The

following sections outline the selected five (out of ten) case studies that illustrate some of those nuances in detail.

Case Study #1: Jane's Pragmatic Journey of Ups and Downs

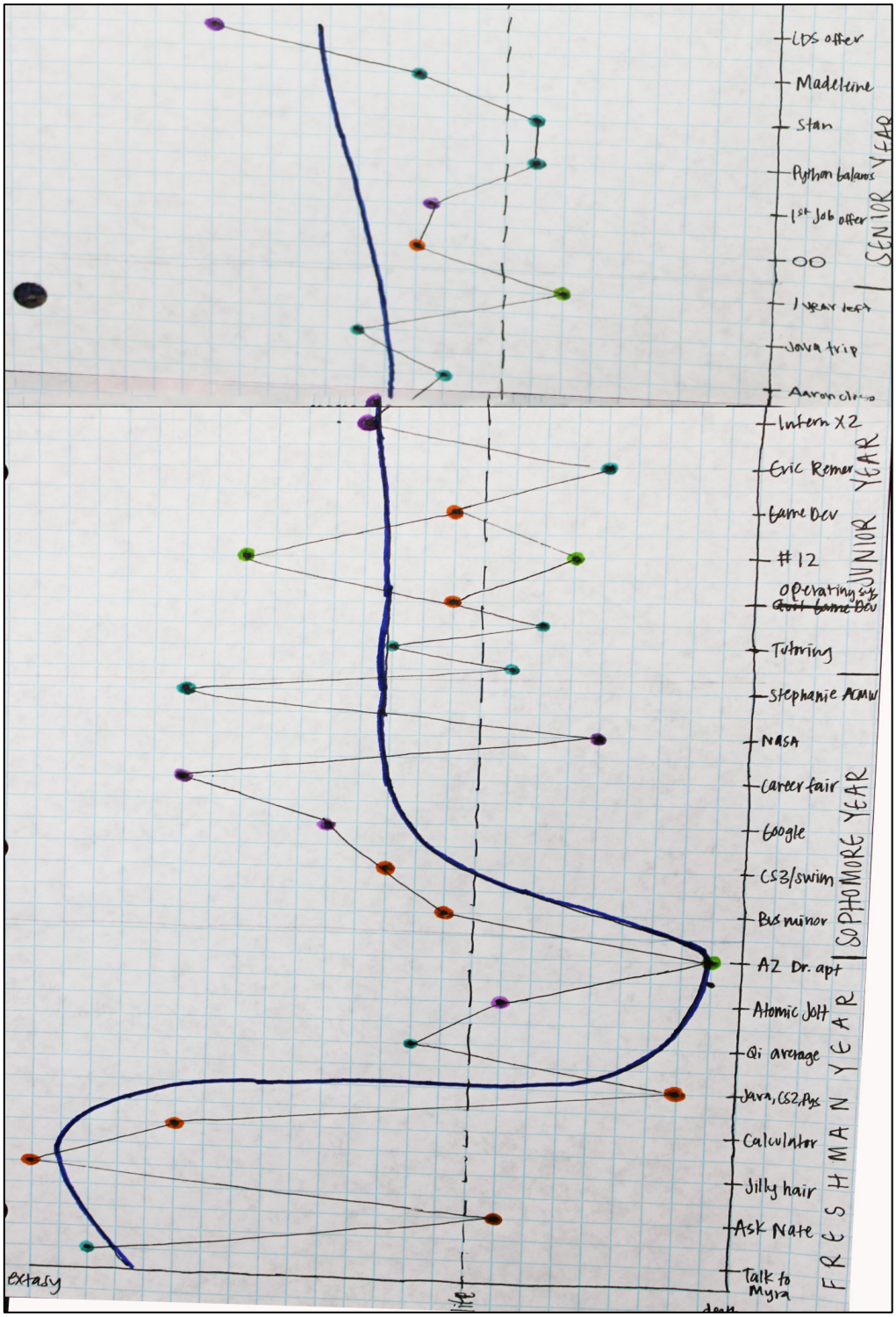
Jane drew a chronological map of her journey, which according to her is "a little dramatic," as it has "the y axis [that] goes from x to c to death" (see Figure 5). Individual points on the map show alternate moments of excitement and "devastation" on her CS major journey, while the solid (blue) curvy line represents her emotional state, on average, across time. At the time of her interview, Jane was a Senior in CS (for more demographic information, see Table 3). She was a full-time student with a programming job inside a non-CS department at the same university.

Jane declared CS as her major in her freshman year after talking to her academic advisor who got her "really excited" about it. At the time, Jane was searching for a major that would allow her to maintain the comfortable lifestyle that she had always enjoyed. As CS was presented to her as the "highest paying major" at the time, she perceived it as the most "viable" option for herself. One that would allow her to maintain the lifestyle she liked. However, her entry into the major was anything but exciting.

As someone who had no prior experience with programming, Jane really struggled through the first few CS classes, which she described as "overwhelming" and overly demanding. More than anything, she struggled with needing to ask for help. As someone who "never had trouble doing homework on [her] own before," having to ask for help so early in the program was "disheartening" to her. As a response, she tried

Figure 5

Jane's Journey Map



working harder. However, despite investing over 60 hours a week in homework, classes remained hard and she kept feeling "incompetent." After four months of such tempo, her work load started affecting her health.

> That was definitely my lowest point, just admitting that my body had even failed. I worked so hard mentally and even my body had rejected it. (…) a 19-year-old working 60 hours a week at something that you struggle with is really hard, and (…)—those were the worst grades I ever got, and so I felt like I didn't even get positive feedback from all that effort. So, like I put in all this work and it didn't feel like it paid off. It did because I passed those classes and those are classes that people frequently have to retake (…), but it didn't feel like success, and so just having all that effort and no success, I think was—it tipped. (Jane, interview)

This excerpt is a good illustration of how difficult the period of enculturation into the major was for Jane. The fact that she passed the classes that many classmates "had to retake" was not rewarding enough for someone who had always been a stellar student. In fact, she felt both emotionally and physically exhausted and contemplated changing her major from CS to something else, such as accounting. Interestingly, according to personal communication with a faculty member, fail rate for introductory classes in this CS department amounted to 15-16% in Fall 2019, which some may say was contradictory to this student's impression.

The following semester, she took a mixture of classes both in terms of topic and difficulty. She combined the last two classes she needed for a CS minor with two business classes, which reduced her course load by three. Finally, "things finally started looking up." While talking about this period in her studies, she said:

> … in CS2 they just drop you in the deep end of a pool and they're just like whoever's surviving at the end can keep going, and in CS3, they teach you how to swim. (Jane, interview)

The analogy she used to describe her third CS semester picturesquely describes the end of

her struggles. Jane mostly credited a “comforting” female “master teacher” for this improvement. She felt that the teacher presented the material so well that “you [felt] you [were] coming up with these ideas” on your own. She compared the experience in this class with CS classes she took previously, where professors were either not good at explaining or the class itself was disorganized, according to her, all of which contributed to her frustration with this major. In CS3, however, she started feeling more competent.

At the same time, Jane received legitimacy in her professional life. She excelled in her business classes and developed a relationship with one of her professors, who became a “really close friend and mentor,” giving Jane recommendations and creating job opportunities for her. More importantly for her sense of belonging in CS, she got an email from a recruiter at Google asking about her progress in the major. At approximately the same time, she got CS-job offers at the university Career Fair, all of which “felt really good.” A crucial moment in her persistence in the major was an insight she received at the Career Fair itself.

> All of our friends who were there from other majors were like ‘nobody wants to talk to us. They only want CS majors,’ and I was like ‘okay, maybe I can tough it out’. This was like a REALLY high point. Because it felt like ‘okay, at least I'm struggling for something good. Like its gonna be worth it in the end. I'm not gonna struggle so hard and then be unemployable’. So, I was just hopeful, a light at the end of the tunnel, a really hard uphill tunnel. I was like at least there's a light at the end. (Jane, interview)

In other words, experiencing acknowledgement from different employers helped Jane realize that she not only had skills, but also that there are many job opportunities for her if she persisted in this major. From that moment on, even though her journey was still a function of high and low points, she started depicting these points as less extreme. After

this semester, she knew that she “was going to finish” the degree, even though she still had her doubts.

For Jane, it was the social aspect of the major, with all the feedback and support she both received and provided that contributed to her persistence from that moment on. She found true purpose and satisfaction in using her knowledge to improve the learning experience of others, as it gave her a sense of competence, and she felt she was improving the experience of others. In one of the stories she shared, Jane mentioned a novice CS student who thanked her for inspiring her to continue.

> She was like “you told me this thing last semester.” I don’t even remember what I had told her, just that it's hard but it's worth it or something. I don’t know. Something like that, but she was like and “that's gotten me through for so long.” (Jane, interview)

Receiving feedback on the difference her help and input made in the life of others was really gratifying and motivating to Jane. She realized she had the power and the experience to give back to the CoP and be the spokeswoman for those in need. In other words, she moved away from the periphery and became a full(er) member of the CoP of her major. That was the moment when she took it upon herself to give back to the community and even try and influence CS culture a bit. If a CS instructor would struggle with teaching a class, she would take it upon herself to talk to the department head and/or ask for more resources from the instructor. At the same time, she started working in the tutoring lab, which gave her a sense of “fulfillment.”

> Somebody came in today crying, and I was able to help them and they're not in despair anymore. That was me last semester. So, I actually had - in CS1 - a tutor who influenced me a lot. (…) Every time I would go in, [she] would tell me “Your code is beautiful. You've done a great job!,” and then she would help me. Just having her say that to me was just “oh, all my effort was worth something

> and she doesn't think it's hideous." It just made me feel so much better. So, like being that person for the next people and knowing what you wanted to hear that "Hey, there's hope. You can do it." That was just really fulfilling for me. (Jane, interview)

As we can see from this excerpt, the importance of social support for Jane's perseverance had been an integral part of her experience from the beginning. Recognizing the effect it had on her experience, she made sure she provided the same for other students, which at the same time gave her a sense of legitimacy and or a sense of purpose. At about the same time she started working as a tutor, Jane started fully enjoying her classes where everything finally "made sense." She felt rewarded for the effort she put in and she felt she finally had "equal footing" with the rest of her cohort. Realizing that she had finally reached the right level of knowledge, however, was a bitter sweet moment for her. After placing second in a programming competition, where she beat teams of good programmers on her own, she felt both happy and frustrated.

> I felt like in the Wizard of Oz when she pulls back the curtain, and she sees the wizard and she's like 'this person I've been fighting so long to find is just like a fat bald man." It's so disappointing (…), I've been working so hard to be at your level and I was already there all along. (…) it was nice to know that I did well, but it felt like crap knowing that I had been so hard on myself for so many years and I wasn't actually doing bad. (Jane, interview)

This snippet illustrates a milestone where Jane acknowledged her own legitimacy, a moment where she finally started seeing herself as an expert, as someone who is competent. Instead of continuing to be hard on herself, she finally started cutting herself "a little bit of slack." She accepted her own abilities as "enough," realizing that no one was good in all programming languages. That spring, she got two internship offers, one of which was at her "reach company" or the company she wanted to work for. Getting the

offers was particularly important to her, as she never used any family connections to get them.

> I just decided I wasn't gonna use my parents' network (…) to get a job, so I got both of those on my own and I was really proud of that. And, I got the one at my reach company, because of a project I did that wasn't even programming, and so that was really cool. (Jane, interview)

As we can see from this excerpt, getting a job without family connections and due to a project she designed on her own was a real moment of pride for Jane. It was moments like these that added to her confidence level. At the same time, she continued to be engaged in the community of her CS major and beyond, helping others to learn programming, such as object-oriented programming and or Java. On such occasions, she got praised for being a good teacher and she once again proved it to herself that she "[had] skills." The fact that she got praised, in front of her parents on one of those occasions, for teaching Java was particularly important as she never took a class on it.

> That was really nice, because he told my parents that and, (…) they were able to finally actually see me teach something and see the skills that I had gained and like worked so hard for. That felt really good, 'cause it was like (…) I have something to contribute. (Jane, interview)

In other words, Jane recognized the value that skills she developed added to other aspects of her life, such as her ability to contribute to the family, which was a particularly proud moment for her. From that moment on, new class successes and new job offers kept her confident and determined to graduate, even though she testified being "sad" when she realized she could no longer change her major upon enrolling into her Senior year. The following example illustrates the level of confidence she reached in her final year.

> I took a class last semester, (…) and I went in to get help one day because I didn't understand something that [the professor] was trying to teach and he told me "It's

> clear that you struggle with Python but a lot of people in the class don't, and so I can't go back over the basics of it," and that was really offensive, because I don't struggle with Python, (…) , and so I feel like if I hadn't had all these years of experience, that would have been really disheartening to hear from a professor (…), but it wasn't (…). I was just like "It's sad that you think that I'm bad at this when I'm not. You're just bad at teaching." (Jane, interview)

In that moment of her academic journey, Jane finally reached a point where other people's comments did not make her doubt herself anymore. She reached a point where she was aware that there was always going to be someone who did not find her smart, "which suck[ed]," but she also realized that it was "not about what other people [thought] about you," but what you thought of yourself. At the same time, she admitted that not caring about other people's opinion was going to be a "life-long" struggle for her.

During her last semester, Jane reported being motivated by positive feedback she received from less experienced women in the program that she strived to help. Having and "naturally seeking" mentors herself, she believed in the benefits the mentorship for novice CS majors. For that reason, she initiated a mentoring program at her department for freshmen women, where female upperclassmen provided support via emails and face-to-face interactions.

In her final semester, Jane found a "really good" job, one where they "[understood] where [her] priorities [were] at," which were travels, flexibility of working hours and salary. When she described her dream job to her employer and they chose to meet her requests, it was a true gratifying moment for her.

> …everything that I worked for, I'm finally getting the payoff that I wanted at the beginning. Like I want the freedom to live the life I want and (…) the things I've done have earned that. That felt really good. (Jane, interview)

In other words, even though her road to degree completion was full of ups and downs, in

the end Jane felt rewarded. A dream was now matching the reality. Earning a CS degree helped her get a job which would allow her to enjoy life in the manner that was important to her. *Working to live, not living to work* was Jane's life motto that drove her choice to study CS in the first place. At the same time, this motto served as one of the main motivators for her to persist throughout her studies. As she herself reported, she never was someone who went home and coded again, as she never liked CS that much. Jane preferred to go home and do other things, such as shopping, reading or golf. The things that she loved doing and the lifestyle that she wanted to maintain were very important to her. Therefore, having a major that would provide her with that lifestyle, even though she was not in love with it, was a "sacrifice" she was willing to take.

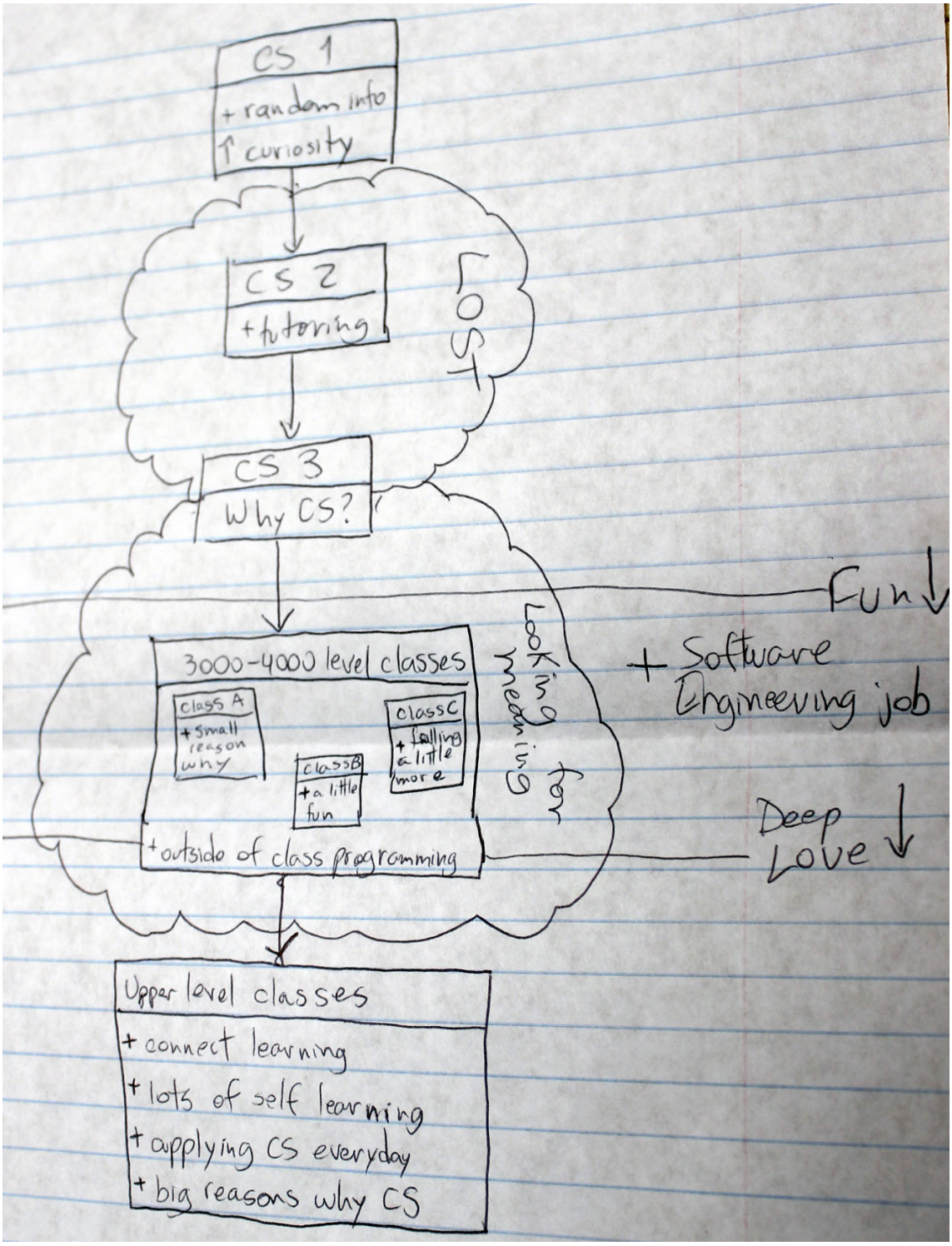
Case Study #2: Joana's Journey of Natural Curiosity

When we met, Joana was a Senior in CS with a part-time job at a software company. In addition to that, she worked as a university ambassador, which paid for 20% of her tuition and gave her an opportunity to engage with the university community. Her mom, who she was very close to, supported her financially by paying the rest of her tuition. In her free time, Joana served as a Trip Leader for University Recreation, taking students mountain biking and backcountry skiing, but she also spent a lot of her free time skiing on her own. Her journey map (see Figure 6) was drawn to look like a programming algorithm, with different CS classes serving as anchors.

Majoring in CS was Joana's choice from Day One at the university. Unlike Jane, who also had no programming experience prior to enrolling into this major, Joana never

Figure 6

Joana's Journey Map



doubted her decision to major in CS, neither did she ever think of changing it. Overall, she really enjoyed programming, so much so that she would frequently spend "4 or 5 hours coding/doing homework, lost, zoned out," which was one of the things that made her most excited about her choice of major. However, she did not feel that way from the very beginning. Fun started towards the end of her Freshman year, after she built enough background knowledge for things to start connecting in her head. Additionally, seeing how much other people struggled with finding a good major that fit their affinities made her appreciative of her own "luck" to find a good fit so early.

Her initialization into the major, however, was not the easiest. She remembered her first CS classes as classes that provided "a lot of random information," which in turn left her confused and uncertain of the purpose of that information. During her second semester, she felt "lost" (this is illustrated by a "cloud" around CS2 on her map, which represents lack of understanding on the deep level). The classes overwhelmed her with technical terms without providing her with a clear understanding of how it can all be applied.

> They just told you "add this! add that!" and [I] was like "why?" and so I was very lost, and I didn't know how is this applicable? It does not make sense and it looked very niche, (…) and then I added the tutoring, so that's what helped me get through that phase. (Joana, interview)

As we can see from this excerpt, when she felt lost and overwhelmed in her program, Joana started going to the tutor lab to get help. According to her, the tutors helped her "get through" difficulties and "get [her] grades up to pass the class." Despite that, she never believed the tutors to be crucial to her persistence in the major, as she only briefly relied on them and only towards the beginning of her studies. According to her, it was her

personality, which she described as a drive "to see things through," that was the main factor influencing her CS retention.

> I am [a] very curious person and I like to ask a lot of questions, so I was always asking questions and not all the time they had the answers (…) I remember like in first CS class I would ask "Oh, why are we adding this on the top?" and they are just like "Just do it!" I am like "ok! That doesn't help!" (Joana, interview)

In other words, Joana's curiosity not only pushed her to ask questions whenever she felt she was not learning, but it prevented her from feeding into the sense of being lost. Instead, if she would not get the answers in class, she would search for them outside the classroom, such as the tutoring lab or in face-to-face meetings with the faculty. In her opinion, the best resource for getting your questions answers had always been the professors.

> I always like tell new students, (…) when I am giving tours of the university, (…) "oh, professors always have office hours" (…), so I promote that…. Idea of like reaching out, 'cause they're the best resource. They are the ones who knows the most and they're right there, like you can access them. (Joana, interview)

In other words, Joana was so convinced in the benefit of reaching out to the professors that she actively promoted the idea to future university students. She considered faculty the "smartest" for the supporting role and was opposed to reaching out to peers as much, as she doubted their ability to help later in the program.

During her second semester, Joana focused on understanding the technical terms. Later, her questioning targeted understanding the big picture, or as she referred to it, "looking for the meaning in CS" (see journey map). During this phase, she felt that every class she took added to the depth of her understanding, which was inspiring her to learn even more. After learning more about the big picture, Joana "started to have fun" with

programming. She found a job in software engineering, but she also participated in hack-a-thons and other outside-of-class programming activities. At the same time, she was taking upperclassman-level courses, all of which caused her to fall "deeply in love" with the major, because she felt that each and every one of those classes opened a new door of possibilities. According to her, at that point, everything she ever learned was finally "connecting." While in the beginning, she spent more time in class talking to the professors or visiting the tutoring lab, at this time she "spent more time outside of class" applying CS to her everyday life. Such approach to learning gave her a lot of flexibility to pursue her other interests, such as skiing.

Skiing, in addition to other extracurricular activities, was part of her effort to maintain life-work balance that eventually influenced her CS persistence. Joana had always been an avid biker and skier despite being immersed in her studies. She believed that physical activity and CS "balance each other out."

> I do enjoy spending lots of time inside, but then you just start like "oh, there is so much time inside" and you start feeling like down or whatever, and then I like go skiing to get like that energy out of my body, too, and I am a very energetic person. So, like, it builds inside of me if I sit down for too long. (Joana, follow-up interview)

As we can see from this quote, even though Joana enjoyed her studies, the sedentary nature of coding conflicted with her need to move. However, instead of developing negative feelings towards the major, she worked in a routine that would balance her energy out through physical activity. What is more, she reported that the "asocial" nature of CS, which was deterring other people from CS, allowed her to have the work-life balance she enjoyed having. While in some other majors you needed to be present on

campus or in an office, Joana felt that CS studies (and eventually a job) could be done from anywhere, which made the major even more appealing to her. As an example, she would often go skiing all day and then do her homework at night inside a Starbucks café.

> For me it doesn't matter that I get to spend like a few hours a day by myself. I just like always had like this freedom mindset kinda thing... So, when I like first started computer science, I knew nothing about it (…) I would go like see job posts and it was like "oh, work remotely!" and I am like "wait! I can live of a van and work as a computer science major" and that was like a big plus of my degree. I wouldn't say that's like … that's what made me choose computer science, but I would say if I look why I love computer science, that's definitely there. (Joana, follow-up interview)

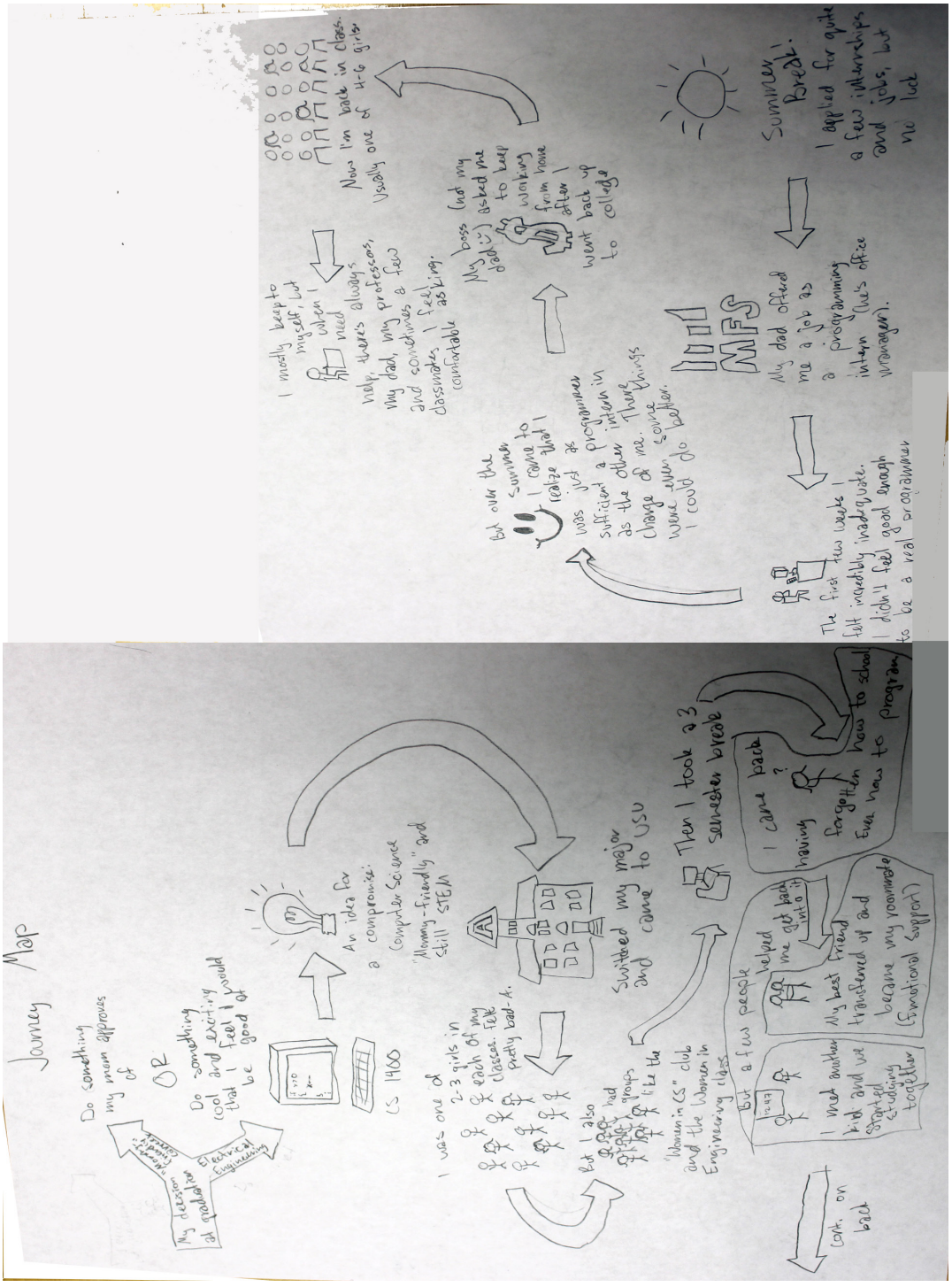
In other words, Joana's retention was influenced by good work-life balance that she worked hard on maintaining throughout her studies. Additionally, the same strategy drew her even closer to CS because it could provide her with that work-life balance that she craved for in life in general. While for some people this CS feature was deterring, Joana saw it as an advantage that allowed her to be free and work from anywhere as long as she had connection to the Internet.

Case Study #3: Shelby's "Mommy Friendly" Journey

When I met Shelby, she was a Junior in the CS major. She was married and lived with her husband who was also a student. Her journey map (see Figure 7) was intricate and descriptive with numerous drawings that were meant to serve as illustrations of each step she took along the way. Shelby started her college experience wanting to major in Electrical Engineering, just like her father. Her parents, however, had "conflicting" opinions about her choice of a major. While her father had always told her that she was "smart" and "capable" enough to "do whatever [she wanted]," her mother was opposed to

Figure 7

Shelby's Journey Map



Engineering, as she did not find Engineering to be a good profession for a woman and her potential role of a mother. She based this opinion on the fact that she had seen too many families where it was "hard on the kids" when their mother was gone all the time. These conversations made Shelby search for a more "mommy friendly" profession early on in her college life.

Shelby took her first college-level classes at a community college while she was still in high school. To prepare for Engineering, she took her first CS class at that time as well. She found it "super cool" and quickly decided that studying CS would be a good compromise (illustrated by a light bulb on her map): both "interesting" and "mother friendly," as she felt she could work from home. Soon after that, Shelby declared CS as her major.

After finishing her Freshman year, Shelby left school to spend three semesters in Germany doing church-related work. During that period, she did not do any programming, which made coming back to school "a little rough." To overcome that obstacle, she found a study partner who had three of the same classes with her. They studied together and slowly, she got "back into the swing of things." At the same time, her best friend moved in with her to attend the same university, which served as big emotional support during this period of re-acclimatization.

That year, when she started thinking about summer internships and her study partner tried to talk her out of it, saying they were not "good enough," she was neither offended nor discouraged. She believed "an internship would look really good on [her] resume," and decided to start searching for one. Eventually, her Dad stepped in and

offered her an internship at his company. It was that particular work experience, and the legitimacy that she received from a senior male colleague that helped her develop her sense of belonging in the major.

> I was kind of concerned because I thought "oh, [my colleague]'s gonna know everything. He's gonna know that I'm like not very good at this, and not very experienced." It kind of surprised me, because he didn't expect me to know everything. I would get stuck and I'd be like… (…) try[ing] all these different things. Then he'd come over to check on me, and I'd tell him, "Oh, I can't get this." He's like, "Oh, no problem. You just have to do this." He was super-understanding. There were even some times where like… I would do something, and he'd be like, "What did you just do?" I'd explain it to him.

As illustrated by this quote, doing an internship next to someone more experienced and understanding helped Shelby both develop her skills and get confidence as her process of learning got acknowledged and her skills got recognized. That experience made her feel "pretty cool" and she realized that she was "not terrible at" programming. What is more, once the internship was over, she got an opportunity to keep working for the same company remotely while still in school (this is illustrated by a dollar sign on her journey map). That incident served as another boost in confidence, as it made her realize her own professional worth.

Interestingly, once Shelby got back to school the following year, she felt that the demographic in the department slightly changed – that is, there were a few more women. Though that change did not necessarily help her own persistence, it made her feel good about the major overall. One of the reasons why she was not affected by the number of women inside her major was her own lack of desire to make friends inside her major. She considered herself to be a "shy person," satisfied with a smaller circle of friends that she had, not many of whom were from her major. Any issues with homework were often

resolved by reaching out to the online communities by "google-ing" the right questions.

Case Study #4: Beatrice's The Visible Woman's Journey

Beatrice was a Senior in CS when I met her. Even though she was interested in computer games as a child, once in college, she decided to study Biological Engineering (BE). However, after a year in the program and a three-semester-long leave of absence due to a church-related service, she no longer enjoyed BE. While away from college, she was exposed to "a lot of stuff on computers," such as "being on a computer, chatting with people, and working on different random things with it," which made her wonder if she would prefer that major instead. Her first semester back, Beatrice took a CS class parallel with her BE classes and realized that she "liked the computers a lot more." According to her, that is when her CS journey started. Her journey is illustrated by a set of comic-book-style images, with each of the six scenes representing a moment significant for her persistence in the CS major (see Figure 8 for the whole journey map).

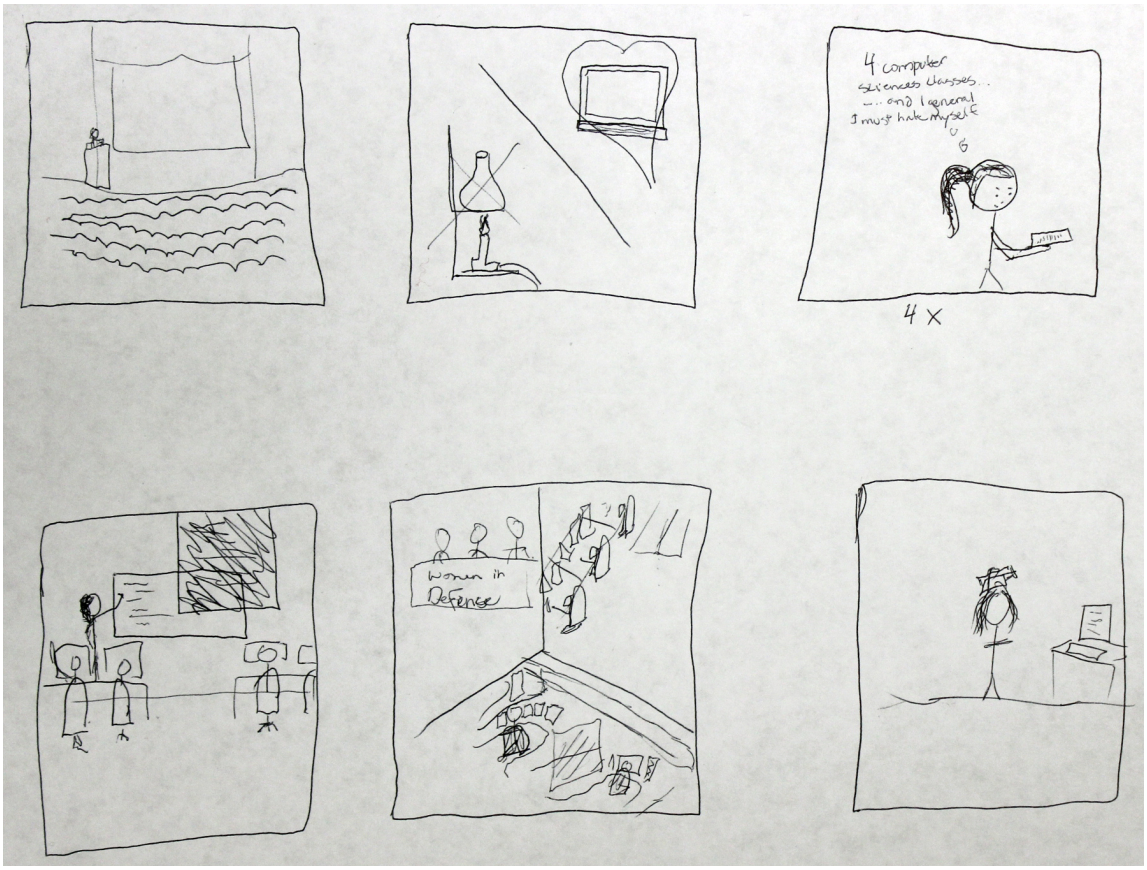
After taking her first class in CS, she got even more interested in the field, and even less interested in BE. As a result, she changed her major into CS. At that point, she had a lot of general requirements already done, and was taking four CS classes and a general each semester, which made her experience hard and at times overwhelming. Despite the challenges, however, she said her love for CS was "cement[ed]" when she found her first CS job, as a Teaching Assistant for a CS1 class.

> I was like, "Oh, I have learned things," because I think I would go along, and it was harder for me to learn a lot of the concepts in computer science 'cause I mean, yes, I played computer games, but I didn't sit there and go build my own computer, or I hadn't even touched programming. I'd never even looked at code

> or anything like that, which a lot of the guys in the class, and even some of the girls in the classes, had done. (…) So, this just kind of reminded me, like, "Oh, I am doing okay, and I am learning things, and I can teach others." 'cause that's, you know, if you can't teach others, then do you really know it very well? So, it just kind of cemented that, and I really enjoy teaching. (Beatrice, interview)

Figure 8

Beatrice's Journey Map



As we can see from this excerpt, Beatrice, like a few other participants in this study, had no prior programming experience despite her interest in gaming. As a result, she was at a disadvantage in her first CS classes in comparison to her classmates. Getting an opportunity to revise some of that introductory knowledge by teaching others and being

good at it, provided her with an opportunity to validate her knowledge and understanding of CS. This consequently confirmed her desire to study CS.

Her next semester was described as "hectic." This is illustrated by the fifth section in her journey map, which is divided into three areas, each representing different elements to one very confusing and busy semester. To begin with, Beatrice got involved with ACM-W (Women in CS) club inside her department as she believed its mission was a good "fit" for her. With that same club, she attended a regional conference where female programmers held panels on their experience. Attending such event was serendipitous and motivational as it happened at a time when she started doubting her CS choice.

> They had all these other panels, and I went to them, and I was kind of just like, "I don't really know what I want to do in computer science," so I was starting to second-guess myself to see if I really wanted to go into computer science because I was like, "What am I going to do? Why do I like this?" And then, I went to that panel and I listened to the women talk about like their experiences in it and everything, and I was like, "Hmm, I think I want to do that." (Beatrice, interview)

In other words, having an opportunity to interact with women who worked in the field helped Beatrice understand what type of a job she wanted to do in the future. Envisioning herself in a particular job, in turn, helped her regain her sense of belonging inside the CS field and motivated her to persist with her major. At that point, she felt that a government job could and should allow her to "make a bigger difference" in the world, which is what she wanted to do, while she personally needed a job whose cause she was able to support. From that moment on, Beatrice never doubted her choice of a major, but she started searching for a job that would provide her with the experience that she wanted to have. She soon found a job, which in addition to her teaching assistantship, made for one "very

busy" semester. At the same time, she applied for an internship with the government, which she got and did over the summer. In the end, she benefited from both jobs. The web development job that she initially got helped her expand her knowledge of the subject matter, as it made her learn something she had been avoiding before. Her summer job, on the other hand, gave her an opportunity to work on a cyber taskforce and learn more about that topic.

Apart from these experiences, which she specifically emphasized on her map, Beatrice also described herself as an individualistic learner, or someone who works on assignments "on her own." She also reported relying on friends for "emotional" and "educational support," "google" for educational support and her family for emotional and financial support. She believed that her involvement in the ACM-W club, and her own personality of someone who reached out to as many people are humanly possible gave her "visibility" inside the department to the point where everyone (both professors and peers) knew her name. This was important as it made the whole experience that much more enjoyable for her.

Case Study #5: Maggie's Journey of Multiple Majors

I met Maggie in her final semester at the university. At the time, she was already done with her mathematics and physics major and was working towards her CS major. When she joined university, however, CS "was not on [her] radar." She accidentally stumbled upon it, as she was trying to fulfill a requirement for her Physics major. She ended up really liking the class and decided to take one more course and or maybe work

towards a minor in CS. Before too long, she was on her way to completing another major, the main reason being that before she found CS, she "hadn't felt like [she]'d found what [she] wanted to do yet in [her] career." This dilemma is illustrated by the first drawing on her journey map, of a girl sitting at a desk with a question mark above her head.

The rest of Maggie's journey map (see Figure 9) focused on the rest of her CS experience and was resembling a comic strip of moments that "stood out [to her] the most" in terms of their relevance to her persistence in the major. Some of those moments, according to her, are the moments she met her first "CS friend," got her first CS summer job, took a particularly insightful class, found another part-time job, as well as her ability to focus on the "end of the tunnel" (with tunnel being her college experience), which served as a major motivation.

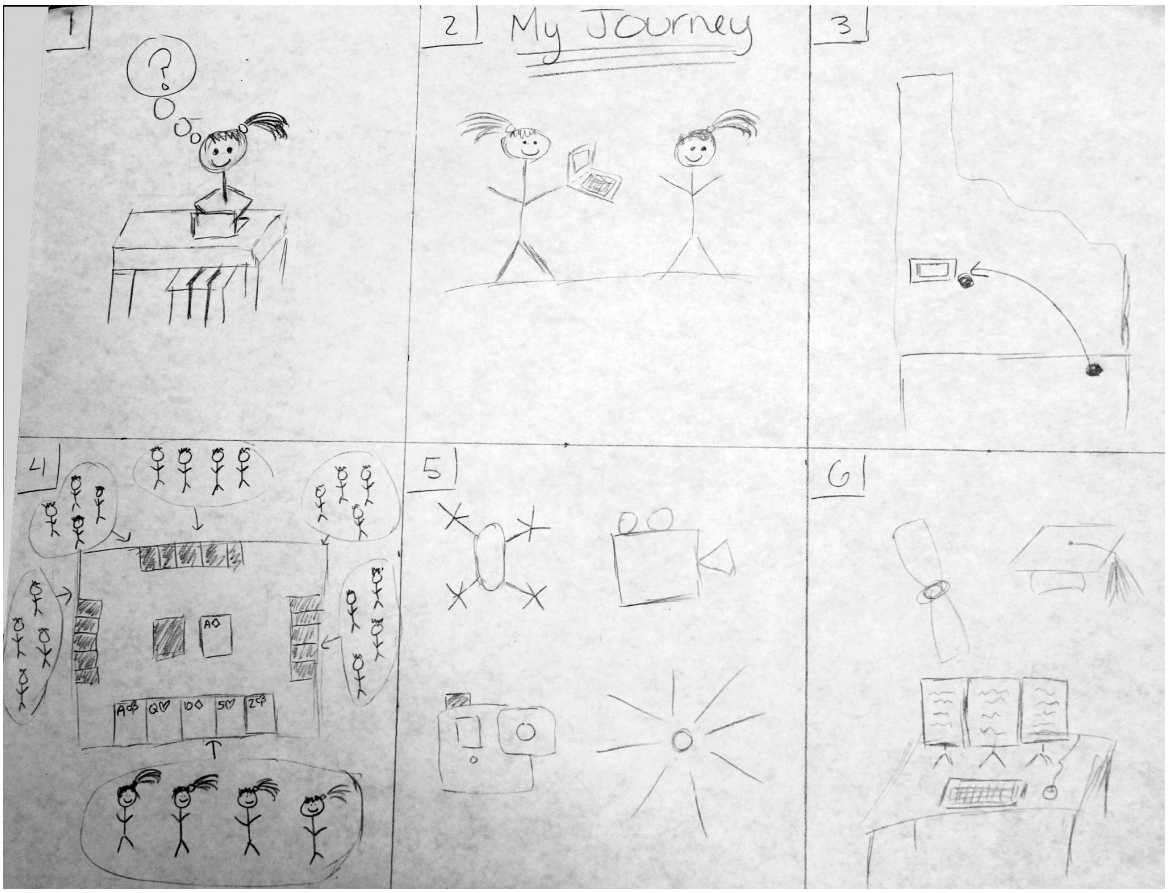
The second drawing on Maggie's journey map represents her second semester taking CS classes, when she met her first "CS friend," a girl who took the same class with her. Maggie thought of this moment as a "stepping stone of being more involved in" the CS community, the moment when she "started building [her CS] network."

> [W]e both were at my professor's office hours on a similar project, and we were both waiting outside, right before, so we just started chatting, and kinda helped—basically figured out each other's problems before office hours, and then just kinda became friends. (Maggie, interview)

Meeting this girl served as a support to Maggie in that particular moment and many other moments in the future, as they remained friends even after her friend graduated. The moment she described, however, symbolically represented a moment of initialization into the CS community for her. She started having her own people in CS even though she was not yet officially a CS student.

Figure 9

Maggie's Journey



That summer she got a job that finally "made [her] realize that computer science was actually what [she] wanted to do." It not only helped her experience the job itself, but it also allowed her to envision what it would be like to work in this industry "day-to-day." Finding that job came as a surprise, as she got recruited from a university Career Fair despite having very limited programming experience. To take the job, she had to move to another state (third image on the map) for the summer, but she loved the experience altogether.

> I didn't have much curriculum, so I had to pick up a lot on the job. And I enjoyed all the things I was learning, and a lot of that—There was a really solid community at that internship. It felt like I became friends with a lot of the coworkers there, and I felt included, I guess, in their culture. And I kinda saw it as some—I never felt like—I always felt like I belonged there, and that I never had to really question if I was able to do that job. I felt capable. And kinda by the end of the summer, I found my niche within my little project, and became a little expert in that area. And then, so the full-time employees would come to me for questions on things. (Maggie, interview)

From this excerpt, we can see that despite her limited programming experience, Maggie was a legitimate member of her work community that summer. At the same time, the field became transparent to her, she was able to envision herself working inside a CS environment, she developed a sense of belonging, and she developed some expertise. According to her, even though it took her a while to catch up with the team, she learned a variety of skill sets in this job, which made the job really enjoyable.

> I think there was just a lot of different varieties of learning, and I think that's why I enjoyed it so much is because I wasn't just learning one track the whole time. I was learning all sorts of different new skill sets. It kept it more engaging, I think. (Maggie, interview)

Some of these "skill sets" included working with new programming languages and or operating systems she had not worked with before. At the same time, the company invested a lot of effort into building "team camaraderie" through "cookie meetings," outreach events and similar efforts. As a result, Maggie really enjoyed working for the company, never felt "isolated" by the nature of her job and got a clear idea of what kind of work environment would best suit her personality. Later down the road, when she ended up in a different part-time job, a job that reflected some of the unattractive CS stereotypes, it was her memories of this first CS work experience that kept her persistent and interested in the field.

> …even though I enjoyed what I was working on, I didn't have much social interaction. (…) I'm more of a person that likes to collaborate on my projects, and work, and it was a little less of that. (…) It's hard to put my finger on. I think it was that my first internship experience was so welcoming, and open, and there was a lot of (…) a little bit more aligned [with my personality]. Even though I enjoy what I do now, I think it's been a good contrast, to help me figure out what environment I'm looking for. (Maggie, interview)

In other words, because she first worked in a job that was aligned with her identity, Maggie did not feel defeated by the isolating nature of her second job. On contrary, the contrast helped her understand what kind of environment was ideal for her personally. Coming back to college after her first summer programming job, she ended up in a really challenging class (forth drawing on the map) – a class that was designed to teach them that not all projects succeed, according to her. At the same time, it taught her how to lead a team, how to "get the best out of people" and how to communicate across teams, all of which she considered to be very valuable. She considered this experience to be the most challenging and "best learning experience" in her whole program. From that moment on, her motivation to persist was based on being able to focus on finishing the degree and graduating.

> It's just knowing what the end of the tunnel's gonna be, and going, and working full time, and all that, has just always been in the back of my head if I'm thinking of having a bad week, or something, just kinda thinking about graduation's getting close… (Maggie, interview)

Apart from the factors she highlighted on her map, Maggie described her learning style as individualistic. While a student in the CS major, she liked to "figure things out" on her own, part of the reason being that she was already an experienced student. Like many other participants in this study, she also made sure she had balance of family life, sports, work and school in her life, and she considered that balance important for her.

Summary

In this chapter, I presented the results for all three RQs proposed in this dissertation study. The chapter is divided into four sections: Demographic Data, Factors Influencing Retention (RQ1), Communities Women Belong to Outside their Major (RQ2), and Participant Stories (RQ3). The results for RQ1 are organized under two groups of factors that influenced retention of women in this study: Social Interactions and Practices. Within the first group, five different types of interactions emerged as important for women's retention in CS inside the major: *Peer Support*, *Faculty Support*, *The Role of Clubs*, *Tutor Support* and *Staff Support.* As far as enabling practices are concerned, nine additional factors influencing retention were defined and described. These include: *Gaining Legitimacy*, *Establishing Balance*, *"Lone Wolf," Finding a Job*, *Proving you Belong*, *Abandoning Perfectionism*, *Finding Online Resources*, *"Just a Really Good Class"* and Other. The analyses for RQ2 unearthed four major communities that women belonged to outside the CS major. These are communities of *External Peers, Family,* and *Co-workers,* with some sporadic mentioning of a few other communities, which were all classified as *Other,* due to their low frequency. Next, in this chapter, I presented a cross-case study of different pathways of ongoing participation (RQ3) of women who succeeded in CS as their major. This analysis is meant to discuss a typical journey of women who persisted in CS. The analysis is followed by five rich case studies of five individual pathways of ongoing participation to show nuance in experience of these women.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Women have been glaringly underrepresented in CS education (Ashcraft et al., 2012; College Board, 2018; Iskander et al., 2013; NSF, 2017), which creates a socially inequitable field (Miliszewska et al., 2006) that lacks diversity and variety in perspectives (Ashcraft et al., 2012; Trauth, 2011; Wilson, 2002). This problem, however, includes two separate issues, the issue of recruitment and the issue of retention (Wilson, 2002), the last of which is the focus of this dissertation.

To date, retention has been mostly investigated from the perspective of women who left the program and in search of factors that influence attrition (e.g., Roberts et al., 2012; Urliksen et al., 2015). The primary goal of this study was, however, to add to the understanding of retention from the perspective of women who persist in the major. To do that, this study adopted the lens of LPP within CoPs (Lave, 1996, 2009; Lave & Wenger, 1991, 2011; Smith, 2009; Wenger, 1998a, 1998b, 2000, 2009; Wenger et al., 2002; Wenger-Trayner, 2015) and aimed to understand the types of social interaction and practices within and around a CS major that provided context for ongoing participation in CS, as well as what some pathways of ongoing participation looked like. The following sections will present the summary of the findings by research question and discussed in comparison to existing literature. These will be followed by sections on Limitations and Future Work.

Summary of Findings and Discussion

Research Question One

RQ1 asked about "Factors Influencing Retention of Women in a CS Major." Based on the theoretical framework of LPP within CoPs, learning can be perceived as an increase in social participation in CoPs (Wenger, 2009) and is interdependent with the practices and social interactions CoP members engage in (Lave, 2009; Lave & Wenger, 1991). In this study, I identified two types of factors that influenced ongoing participation of women in CS: different social interactions and practices, both of which are discussed in the following sections.

Social Interactions

All reported interactions inside the CS major were closely examined to identify those that enabled these women's retention in their CS major. The analysis revealed four categories of social interactions that supported retention. While the findings on relevant social interactions align with previous literature on peer and faculty support, they also add nuance to the understanding of their type and significance. The results also reveal some interactions that have not been mentioned that frequently in literature.

Interactions that CS women had with peers, for instance, were found to provide the most frequent type of social support inside the major. All the participants, regardless of whether they preferred individualistic learning approach, or they liked to study in groups, reported relying on peer support to some extent, mostly for different educational and emotional reasons. Women did not report preferring one type of interaction over

another but relying on female versus male or mixed support was less frequent (see Table 7), most likely due to low numbers of female peers in the major. Prior literature suggested that interactions with male peers often had a negative effect on women's retention (e.g., Barker et al., 2009; Benbow & Vivyan, 2016; Bunderson & Christensen, 1995; Clegg & Trayhurn, 2000; Cohoon, 2001; Gokhale & Stier, 2004; Gürer & Camp, 2002). In this study, a few negative incidents with male peers were also reported, mostly involving sexist remarks, but as these were not within the scope of this study, it is not clear how widespread they were. One possible explanation of low frequency with which these were reported is that due to the nature of this study (focus on retention and not attrition), women did not reflect on the negative interactions as much. Another explanation is that some women are simply not fazed by negative remarks, as reported by three of the women in this study when discussing the incident with the professor who apologized about the sexist remark one of his students made in class.

Interactions with faculty were not nearly as frequent as peer interactions but were also found to be important for women's persistence in CS, both educationally and emotionally. While there is some research on how faculty can deter women from CS majors (e.g., Barker et al., 2009; Benbow & Vivyan, 2016; Bunderson & Christensen, 1995; Denner et al., 2014; Gokhale & Stier, 2004; Kapoor & Gardner-McCune, 2018; Medel & Pournaghshband, 2017; Singh et al., 2007; Varma & Hahn, 2007), research on how encouraging and engaged faculty can influence retention of women in CS (e.g., Ceglie, 2009; Cohoon, 2002a, 2006) is less common. This study adds to literature by illustrating several ways in which faculty support was found to have a positive effect on

the retention of women in this study. Some of these included providing concrete educational and emotional support, all of which supported women's legitimate participation in this major. The examples of support they received and valued came from both male and female faculty members, with female faculty being mentioned less frequently (see Table 7 for more details on gender breakdown of faculty interactions), most likely due to low number of female faculty in their department.

In addition to the well-researched types of support (i.e., peer support and faculty support), this study presents some evidence on the benefits of interactions within some of the embedded subcommunities inside and outside the CS major, such as the Tutor Lab, the Linux Club, ACM-W, the University Ambassadors and so on. According to Lemke (1997), CoPs often have complex structures that consist of smaller subcommunities. These help the CoP increase its efficiency and address the needs of different community members (Wenger, 2000). One such subcommunity inside the CS major CoP that supported these women's retention was the Tutor Lab. Tutor Lab was run by senior CS students and organized by the department to support all students at the periphery of their participation, i.e., during their initiation period. All women reported using the help of tutors in the first few semesters. As a matter of fact, most of them reported it as the first resource they used that was often crucial for their retention during the initiation period of their studies. The help received was mostly academic, but some examples of emotional support were also recorded. Research suggests the period of initiation is the most problematic in terms of female attrition (Biggers et al., 2008; Miliszewska et al., 2006; Stephenson et al., 2018), which implies that the use of tutoring programs could increase

female retention in CS majors. While many researchers emphasize the importance of tutoring labs for the retention of women and minorities (e.g., Binkerd & Moore, 2002; J. Brown et al., 1997; Miliszewska et al., 2006; Nett, 2008), the influence of tutoring on the retention of women in CS is not a well-researched topic. Staehr et al. (2000), for example, found that a combination of peer mentoring, peer tutoring and supplemental instruction increased retention of first year female students. Cottam et al. (2011) found that tutoring helped CS1 and CS2 students succeed in current course work and build confidence for future CS course taking. However, these authors did not investigate female students separately. A different study of the same intervention presented a case study of a female student, who perceived her female tutors as encouraging, trustworthy and knowledgeable, all of which helped her declare CS as her major (Loos et al., 2005). Miliszewska et al. (2006), on the other hand, found that gender of the tutors was immaterial to CS women, despite the fact that women were more likely to seek female help. More research is needed to understand the role of tutoring on the persistence of women at the periphery of CS education, as well as what kind of support from the tutors is most important for female retention in CS.

Finally, this study identified several clubs and organizations, inside and outside the major, which were important for these women's persistence in CS. The clubs inside the CS major (e.g., Linux, ACM-W), for example, provided exposure to the more seasoned members of the CoP, they expanded these women's understanding of the field and or taught some of them some survival skills for male dominant environments. ACM-W, in particular, was organized by the department as another subcommunity inside the

major to support women's membership in the CoP of the major. However, despite favorable testimonies about ACM-W, only four of the women mentioned being members of this club. Additionally, the variety of clubs and organizations mentioned across different interviews make it difficult to highlight implications for these findings. More research is needed to investigate the importance of ACM-W and the female role models inside it, as well as the role of other clubs and organizations in general to the persistence of women in CS majors.

Practices

All reported practices were examined to identify those practices inside the CS CoP which supported these women's retention in their CS major. Nine practices emerged. One of the most frequent practices that emerged was the practice of *gaining legitimacy*, which originated both in school and at work. Receiving legitimacy in school made women more excited about the major, while legitimacy received at work helped them feel like programmers. Obtaining legitimacy helped the women in this sample develop a sense of belonging within the CoP of their major and it contributed to their overall positive experience. This is aligned with the theoretical framework used in this study (Lave & Wenger, 1991; Wenger, 1998b, 2010), which posits that when learners are acknowledged as competent, they can develop a sense of belonging to the community. In this study, I also found that apart from finding legitimacy in others, the participants often needed to be able to personally acknowledge themselves as competent. Whether the feeling of legitimacy developed after deepening their understanding of programming in classes and or by teaching and mentoring others, finding a way to acknowledge your own expertise

and value within the major was equally important to receiving such acknowledgement from others. While literature on LPP in CoP often describes learning, participation and identity formation as negotiated and co-constructed (e.g., Buysse et al., 2003; Holmes & Meyerhoff, 1999; Jacoby & Ochs, 1995; Wenger, 2000, 2010) between the community and the individual. Legitimacy is often described as something that is given by the community (Wenger, 1998b). In a case study of two individuals learning a language in similar environments but with different success, Back (2011) argues that legitimacy can also be co-constructed. This dissertation study provides additional empirical evidence for that claim.

Another practice that emerged as important for the retention of women in CS was the practice of *establishing* (school) work-life *balance*. Results in this study indicate that women established work-life balance in one of two ways: either through a CS-unrelated minor or by approaching schoolwork in moderation, while leaving enough time for other aspects of life, such as religion, sport, social life and or relaxation. So far, research has only indicated that women's concerns about future *family*-work balance were a determining factor in their retention (Beyer, 2014; Beyer et al., 2005) and that students from Carnegie Mellon, a program with good gender balance and retention, had good life-work balance in general (Frieze & Quesenberry, 2015), which is not exactly the same as work-life balance. Even though the importance of balanced life may appear as common sense, to my knowledge, no existing research investigated the extent to which such balance influenced retention of women in CS. Thus, further research is needed on the relationship between work-life balance and attrition and or retention in CS.

The majority of the women in this sample described themselves as having at least somewhat individualistic ("*lone wolf*") approach to learning, either due to their personality traits and or beliefs about how they learned best. This is similar to Callahan and Tomaszewski (2007), who found that individual or independent engagement was one of the two ways women working in a male-dominant CoP engaged inside the community, in addition to forming sisterhoods. The authors defined sisterhood as a tight network of women who had supportive personal and working relationships regardless of the hierarchy. In this study, I found no evidence of such sisterhoods, but women did report relying heavily on their peers and faculty, some of which were women.

Another practice influential to participants' retention was *finding* a CS-related *job* while still being a student in the program. These work experiences were widely positive for the women, as they helped them learn new skills while being exposed to explicit learning opportunities. Not only did such knowledge give them an advantage at school, but it was also crucial to their persistence, as it broadened their perspective on CS, allowed them to envision themselves in the field and helped them develop a sense of belonging. This is an important finding as many CS programs could adopt mechanisms to recommend and or facilitate job searches based on positive experience of senior women in their program. However, there is very little research investigating the relationship between work and retention of women in CS. However, Kapoor and Gardner-McCune (2018) did find that positive experiences with CS internships positively influenced female persistence in the major, while negative ones made them realize that they did not want to work in a certain area or position. It could be that the sample of women in the present

study had a positive experience with their first jobs, which consequently supported their persistence in their CS major. More research is needed to investigate the influence of working in the field during your studies on the retention of women in CS.

Four of the practices identified in this study were mentioned with less frequency, but they still somewhat influenced the retention of the participants in this study. For example, mostly in the beginning of their CS studies, women felt that they sometimes needed to prove to both themselves and the community that they belonged in this major. This is different from self-legitimacy as these attempts were not accompanies by feelings of legitimacy. On contrary, they were accompanied by self-doubt. This practice of *Proving you belong* may be related to what Wenger (1998b) called one of the key characteristics of CoPs. He said that there has to be a substantial overlap in participants' descriptions of who belongs. Such overlap, however, is historically lacking between the description of the dominant white male cohort and this historically minoritized, occasionally marginalized, group of women in CS (e.g., Barker et al., 2009; Benbow & Vivyan, 2016; Bunderson & Christensen, 1995; Clegg & Trayhurn, 2000; Gokhale & Stier, 2004). Women have often been found to leave CS as a major because they don't feel welcome or don't feel like they belong. Finding that women who persisted in CS used different active (e.g., open confrontation) and or passive (e.g., solving a difficult equation in front of the whole class) strategies to resist feeling like an imposter is important, as we can integrate such strategies in programs designed to support women in CS. While I do not argue that women should "toughen up and adjust" (Margolis & Fisher, 2003), as that would shift the responsibility of retention to the women, I do think

women at the periphery of this CoP can benefit from learning about all the practices that helped other women persist.

Abandoning perfectionism was a practice that represented more of a milestone than a continuously used practice. Most women in this study reported struggling with perfectionism, in a sense that they wanted to have perfect grades and be at the same (high) level of competence as the "best" people in class. However, their understanding of CS competence was skewed by lack of experience within this field. According to Wenger (1998b, 2000), competence is not a display of socially constructed knowledgeability, but it also consists of individual's ongoing and changing experience. Therefore, it differs from one person to the next, based on their individual experience. Once the women in this study developed an understanding of what it means to be competent in CS, which is similar to Wenger's definition, as CS is a skill-based field, they abandoned the tendency to strive for perfectionism. This was described as a pivotal moment in their retention, as it allowed them to have a stronger sense of belonging, while at the same time practicing more kindness towards themselves. This is an important finding because it highlights another retention strategy that can be included in intervention programs aiming to support female retention in CS.

Another practice that women considered crucial for their persistence in the major that no one explicitly taught them or introduced them to, was *finding online resources*. Rather than saying that this was a practice they used every day, the women mostly testified to the importance of developing this skill, as well as how lack of such skill in the beginning of their studies impaired their progress. *Such sk*ills consisted of knowing how

to ask the questions online, in a way that would result in receiving answers that would help them complete their class assignments. To my knowledge, no studies discuss the importance of this skill for the persistence of women in CS.

Finally, everyone mentioned one or two classes that were crucial to their persistence. Some of the reasons mentioned were the fact that the class helped them visualize what it was like to work in CS industry, and or they got an opportunity to learn an important skill. In other words, these classes presented the women with authentic learning opportunities, as they allowed them to perceive an alignment between the instruction and the broader CS CoP (Lave & Wenger, 1991), or they were perceived as authentic because both their topics and assessment were aligned with what was taught (Shaffer & Resnick, 1999). Exposure to authentic activities in authentic practice is central for learning (Brown et al., 1989), according to the theoretical perspective used in this study. It is also something that a lot of CS courses struggle with (Guzdial & Tew, 2006).

Research Question Two

RQ2 asked about "Communities Women Belong to Outside of their Major." Upon analysing data for RQ2, I found that women belonged to four other communities outside their major: their external peers, community of co-workers and their family, in addition to a couple *Other* communities. This is aligned with Tinto's (1987) model of retention, which suggests the importance of external communities for retention of university students. Our earlier review of literature revealed that research on the influence of external communities to the retention of women in CS is scarce (Pantic & Clarke-Midura, 2019). The findings to RQ2, therefore, contribute to that gap in literature, as we learn

several important things about the external communities women in CS belong to that supported their retention in different ways.

To begin with, we learn that women from this study, who persisted in their major, received a lot of emotional support and encouragment from their external peers, such as their roommates and friends who did not belong to the same major. Such importance of external peer support is similar to earlier studies that found external peer support to be one of the strongers predictors of women pursuing CS (see Dee et al., 2009; Denner et al., 2014; Frieze & Quesenberry, 2015; Singh et al., 2007), while lack of such support led women to leave this major (e.g., Rosson et al., 2011). In this study, I did not find any evidence of women being inspired by their external peers to pursue CS, but external peers' emotional support was often cited as important for their retention.

Another community these women felt strongly connected to was their family. While mothers and partners (i.e., husbands and boyfriends, as reported by the women) were found to provide emotional support to their persistence in the major, for some women fathers served as brokers (Wenger, 1998b). Fathers either helped their daughters enter CS CoP or they created bridges with different CS CoPs, such as work. Often, fathers also served as academic support. This is similar to other literature on parental support. Frieze and Quesenburry (2015), for instance, mentioned examples of CS women playing games with their fathers, discussing CS careers and or learning programming. Laluvein (2010) found mothers' brokering role to be crucial for bridging different CoPs included in their child's educational experience. Other studies also found father (Frieze & Quesenberry, 2015) and family support to be important for recruitment (e.g., Ashcraft et

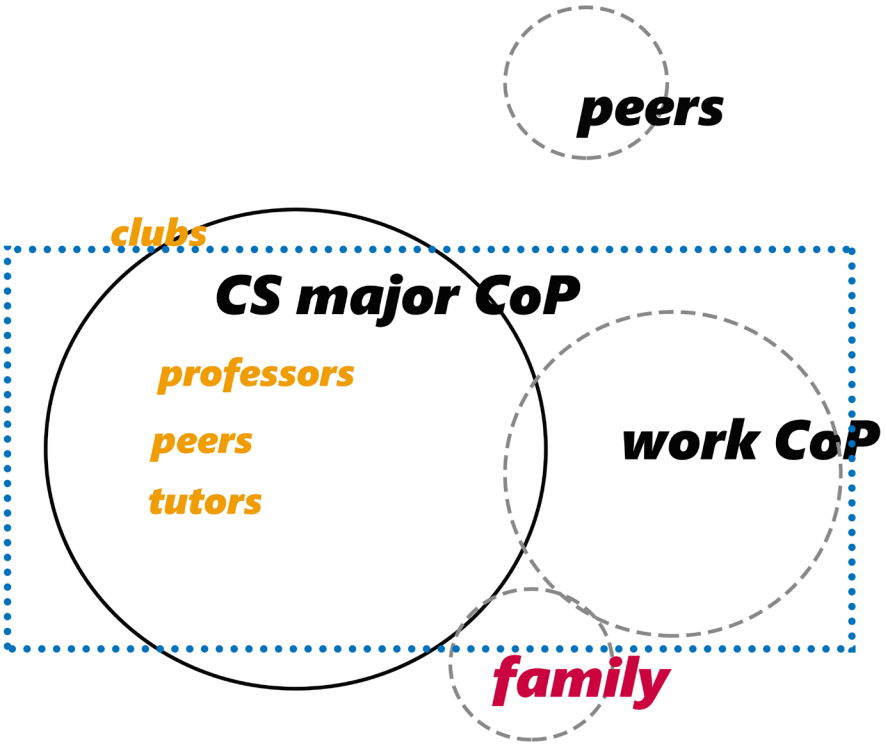
al., 2012; Redmond et al., 2013; Singh et al., 2007) and retention of women in CS (e.g., Denner et al., 2014), as well as their vocational self-efficacy (e.g., Turner & Lapan, 2002), CS interest (e.g., Clarke-Midura et al., 2018), and higher utility value beliefs (Denner, 2011). Even though some research showed evidence that women received less family encouragement than men to stay in CS (Miliszewska et al., 2006), and were sometimes exposed to gender biases even at home (Gürer & Camp, 2002), I found no similar evidence for this group of participants in relation to studying CS. Those who did mention parental support, talked about the positive role parents played in their retention. These findings suggest there may be a relationship between family support and retention in CS. Further research is needed to explore the nature of that relationship.

The third community women reported belonging to outside their major was their work community. As we have seen from the findings in RQ1, their work community provided them with legitimacy, enabled them to test their competencies in practice, and helped them build richer practical skills than the ones they build in school. In addition, *Finding a Job* was one the practices that supported their retention, as it allowed them to see what it was like to work in CS field and whether they could succeed in it. This finding is similar to Fincher and Tenenberg's (2006) findings that experiences and interactions with work community can strengthen commitment to CS education. However, studies on the role of work communities to retention of women in CS are rare (e.g., Beyer, 2014; Beyer et al., 2005; Kapoor & Gardner-McCune, 2018). This study adds to the existing body of literature, as it highlights several roles that work communities play in the retention of women in CS majors.

From all the findings in RQ1 and RQ2, we can see that in the present study, women's learning of and retention in their CS major happened at the intersection of several different CoPs, and not just within the CoP of their major (see Figure 10). Learning (blue dotted line) within their CS major was strongly supported by their work CoP. Some fathers also had a role in both their learning and retention, at certain points in time, as they not only provided emotional and academic support similar to other family members, but also served as brokers (Wenger, 1998b) into and between different communities. In addition to their family and work community, participants in this study

Figure 10

Communities that Women Belong To



Note. Full black line: CS major CoP; Orange: CS major subcommunities and other support groups. Blue/dotted line: CoPs that contributed to women's learning. Grey/Interrupted line: external communities. Red: Family where fathers served as brokers sometimes.

also reported belonging to a community of peers external to their major that also supported their retention by providing emotional support. Such multimembership across different CoPs, as Lemke (1997) called it, contributed to the development of their mastery by helping them develop diverse competencies (Wenger, 1998a, 2009) and validate the knowledge and practices (Fincher & Tenenberg, 2006) that they earned inside their major.

Even though in RQ2 participants only specified belonging to three external communities, some findings in RQ1 and the category *Other* from this RQ hint at the importance of several other external communities for the retention of women in CS. Specifically, the importance of finding online resources practice and achieving work/life balance raise the question on whether a certain online CS CoP or a certain community in relation to their extracurricular activities (e.g., sport or church) is also a community that they actively belonged to. The nature of this study did not allow for such relationships to be fully explored and more research is needed to test the validity of these assumptions.

Research Question Three

RQ3 asked about "Women's Participation Pathways in a CS Major." Third research question investigated *typical participation pathways that women followed as they worked towards the completion of their major.* This question is rooted in models of personal histories (Li et al., 2009) that more seasoned, or in this case persisting, members of the community (i.e., exemplars) engaged in. To my knowledge, there are no studies currently available that unearth such models of ongoing participation for women in CS majors, nor what some of them may have in common. In that sense, this dissertation is an

important contribution to the literature about LPP in CoP and retention of women in CS majors.

The previous chapter laid out a cross-case study narrative outlining commonalities on women's participation in the CoP of their major, followed by five individual stories of ongoing participation in social practices inside this CoP that contributed to retention of these women in their CS major. I will now discuss those findings, as well as what kind of theoretical implications they have.

Prior to engaging in their major, the majority of women in this study did not have any programming experience. According to research on retention of women in CS, women are more likely than men to enter college with no prior experience in programming and or computing (e.g., Denner et al., 2014; Gürer & Camp, 2002; Liu & Blanc, 1996; Margolis et al., 2000; Margolis & Fisher, 2003; Ragsdale, 2013; Staehr et al., 2000). As a result, this factor often influenced their attrition. However, in the present study, all the women interviewed persisted in their major, which suggests that lack of prior experience does not necessarily predict retention

The CS major reflects Wenger et al.'s (2002) definition of CoPs, as the CS major is a place where students who are passionate about CS come to build their knowledge and expertise in CS by interacting with their faculty, tutors and peers on ongoing basis. The CS major CoP is situated within a broader university community, and its boundaries (Wenger, 1998b) are easily permeable, as students from other majors are allowed to take CS classes without officially enrolling into CS. This, in turn, gives students the opportunity to explore CS without officially enrolling, and or to accidentally "stumble

upon" CS by satisfying requirements for some other major, as it was the case with some women in this study. In other words, different women had different entry points into the CS major. While some women declared CS as their major from the beginning, others transferred from other programs and institutions at different points in time. Women who came with their general courses already completed were put on an accelerated all-CS-course curriculum, and were often given the status of a Junior student despite the fact that they barely joined the program. Even though these women had access to the same resources as anyone else, taking an accelerated curriculum made their engagement in the CS CoP additionally difficult, as it was opposed to the gradual process of taking up the practices, which characterizes learning as LPP in CoP (Hoadley, 2012; Lave & Wenger, 1991; Toohey, 1998). Even though all the women in this study persisted in their major, this finding raises awareness that not all entry points into the major are adequately supported. More research is needed to explore the connection between women's entry point into their CS major and their retention, as well as what interventions could be put in place to support this group of women.

However, it is important to say that no one's introduction into the CS major in this study was easy. Most women described it as "confusing," "rough" and "challenging," regardless of their background or entry points. One of the reasons being that some practices, such as the finding online resources and or the language of the field were not transparent to them. Transparency is a crucial source of increased participation (Lave & Wenger, 1991). Many other studies found women to be more likely to get overwhelmed by CS terminology and programming in their first CS classes due to absence of prior

experience (e.g., Liu & Blanc, 1996; Roberts et al., 2012). For that reason, a lot of research has focused on the importance of designing introductory CS classes for students who have low prior experience (e.g., Alvarado & Dodds, 2010; Beyer, 2014; Dekhane et al., 2017; Dekhane & Napier, 2017; Gokhale & Stier, 2004; Latulipe et al., 2018; Liu & Blanc, 1996). None of the women in my study mentioned taking such courses even though a lot of them mentioned classes that provided them with authentic experiences. The CS program that they all belonged to did provide access to organized social support on the periphery of their participation (Lave & Wenger, 1991), which in this case were the first few semesters of their CS studies. This support included two embedded subcommunities (Wenger, 2000): The Tutor Lab and the ACM-W club. Tutor lab was a place where women could expose themselves to more seasoned and senior students of the program, who provided programming support. The ACM-W club provided emotional support by exposing them to more seasoned female students (i.e., exemplars) (Lave & Wenger, 1991) and or teaching them different coping strategies. Most women reported using tutor support during the first few semesters of their program and a few reported actively participating in the ACM-W club activities. Positive experience with both of these subcommunities helped the women identify themselves with the CS CoP, which is consistent with Wenger's (2010) theorizing about LPP within CoPs.

Some research also mentioned that dis-identification can happen when CoP members do not participate in meaningful practices (Probst & Borzillo, 2008). Interestingly, meaningful practices and learning opportunities were an integral part of these women's participation pathways. In addition to taking relevant classes, they found

CS-related jobs after taking only a few CS classes. These positions represented another form of "apprenticeship" (Lave & Wenger, 1991), which happened with special supervision of older more seasoned co-workers, who embodied the practice and provided them with legitimacy. That is, their co-workers acknowledged them as competent from the beginning, regardless of their mistakes and need for help (Wenger, 1998b). They reported that what made these work experiences meaningful is that they were not marginalized (Wenger, 1998b) with menial tasks, but were given access to a full range of activities and the repertoire of the CoP from day one (Lave & Wenger, 1991). During that period, they not only gained explicit experience and knowledge, but they learned how the CS CoP works, which is similar to what Olson (2015) found. Consequently, *finding a job*, which was a practice every woman in this study adopted, empowered them to envision their own success in this major and persist in it.

After returning to classes, women's participation moved further from the periphery. They mentioned learning to "talk like a nerd" (Lave & Wenger, 1991; Smith, 2009), started sharing "war stories" with younger members, and or actively worked on supporting novice students. At that point, most women had an established support group among their peers, which is aligned with literature that found peers to be valuable resources for learning and support (Hodgkinson-Williams et al., 2008; Lave & Wenger, 1991; Rogoff, 1993) in CoPs, in addition to masters, which in the case of this study were faculty members. Faculty support was also found to be important in this study (see RQ1 in Results for more detail).

As theorized by Lemke (1997) despite average resemblance between different

pathways of different women, different women created unique connections depending on how they engaged in the CoP of their major and beyond. Similar to Dawson (2013) and her study of health professionals, the pathways of ten women in this study differed in many aspects. Thus, one of the main contributions of this dissertation are the detailed outlines of five pathways of women's ongoing participation in their CS major. Additional five case studies are provided in the Appendix I. In the absence of live role models inside the major, which is a problem CS majors are facing due to severe underrepresentation of women, having narratives of success stories available is paramount.

Limitations and Future Work

This study has several important limitations which need to be considered. To begin with, the sample for this study has been drawn from a single university in the Intermountain West, which affected the sample in several different ways. For one, the study is not (neither was it planned to be) generalizable to other universities or contexts. In other words, some of the findings might be specific to the culture of the Intermountain West and or this particular university. Next, the university is set in an area that is predominantly Caucasian (U.S. Census Bureau, 2017). Such racial make-up reflected in the sample of this study, limiting the findings mostly to the perspective of white women. It is also important to mention that recruiting women with upperclassman standing was challenging as they made up only about 10% of the upperclassman standing (G. Hanson, personal communication, March 02, 2017). As a matter of fact, I interviewed 10 out of 11 women who volunteered to participate. As a result, I collected data from both Juniors and

Seniors, as it was originally planned. However, upon analyzing the data, I realized that Seniors had richer stories to share, as it could have been expected. Interviewing more Seniors or an exclusively Senior sample might provide a richer study, as they spent more time in the major and had more practices and interactions to talk about. On the same note, future studies on retention of women in CS should focus on a more diverse sample of women who come from different areas of the US. As non-white women make 7% of those who graduate with a CS baccalaureate degree (NSF, 2017), special effort should be put into recruiting them for future studies to make sure their perspective is also being represented. Such samples could help confirm, contrast and or refine the findings from this study with additional insights from different institutions and diverse groups of participants in terms of racial and ethnic make-up, while at the same time getting access to richer data.

A second limitation refers to the type of data collected in this study. This study is based on self-reported data through interviews, journey maps and focus groups, where the participants tried to recollect practices and interactions which happened throughout their undergraduate education, sometimes for periods longer than four years. Though I did have access to some of their daily routine through ESM, this real-time data is only 14 days long and very limited in scope and depth, in addition to also being self-reported. It is well-known that human long-term memory is limited and unreliable (Pugh, 2017), so it may be that these women's testimonies are also incomplete or not fully reliable. Future research could do an ethnographic study of this population throughout the years, and or a different type of longitudinal study where they are observed and interviewed at several

different points in time throughout their studies.

The third limitation appeared in reference to the ESM data and the usage of the theoretical framework used in this study. Even though use of ESM methodology is innovative, and it provided insight into the daily routine of women in CS majors which has never been done before, without other studies using the same methodology, there is no benchmark to compare female experience with. More specifically, we do not know if women who persist in this major remain in such small numbers because they are the only ones who manage to adopt a routine that is typically male, or if they are the ones who persisted regardless of being different in their approach to life. In other words, the use of a benchmark is not to compare women to men in the old "deficit" type a way, but to identify areas where women have been marginalized and denied of learning opportunities.

Similarly, while there are many studies focusing on the gender gap (e.g., Ashcraft et al., 2012; Denner et al., 2014; Fisher et al., 1997; Gürer & Camp, 2002; Liu & Blanc, 1996; Margolis et al., 2000; Margolis & Fisher, 2003; Ragsdale, 2013; Singh et al., 2007), we do not know if men and women, who have been historically marginalized in CS majors, have access to the same resources inside the major, learning the same practices and engaging in the same interactions which set ground for their ongoing participation. The nature of this study did not unravel too many negative experiences either. Future research should compare female experience to male experience and aim to unearth how access to the CS major CoP is gained by these two groups, as well as if there are any resources and learning opportunities that even successful women in CS majors do

not have access to.

Finally, this study was designed to look at retention inside the CoP of these women's CS major primarily focusing on practices and social interactions inside the major. However, several other communities and CoPs emerged as important for their learning and retention in CS. Their learning seemed to have happened at the intersection of the CoPs of their major and work. There are some indications of the importance of the online CS community, even though they did not specify actively participating or belonging to it. A practice that emerged as important for their retention, Establishing Work/Life Balance, hints at the potential importance of some other communities, such as sport- or church-related activities. However, as such questions were not specifically asked, there is a question on whether the data provided on outside communities was complete. In particular, I am interested in further investigating how they learn the to find online resources and to what extent and how they rely on the online community.

Conclusion

Studying retention of women in CS from the perspective of LPPin CoPs has several important implications for CS departments as they strive to broaden participation of women in CS majors. Some of these implications are social, while others point out practices that can be encouraged and supported, which would in turn support retention of women in CS majors.

To begin with, this study reveals the importance of building a community inside the CS major where educational and emotional support among peers, and among students

and faculty is cultivated and encouraged. To achieve such culture, I posit that both students and faculty need to be familiar with the above-mentioned social benefits for retention of women in CS, as well as why gender equity is important and should be supported by everyone inside the community. This can be done through professional development for faculty, but it can also be emphasized to students during orientation, tutor training and similar activities.

To help female retention during the initial period of enculturation into the major, it is also important to organize help at the periphery of the CS major community. This can be done through organizing special subcommunities that can support women educationally (e.g., Tutor Lab) and or provide them with opportunities to get exposed to more seasoned members of the community and receive emotional support (e.g., Tutor Lab and ACM-W club). The department that my participants came from had such subcommunities available inside the department, and the women reported them being very important for their retention in the major, especially in the beginning of their studies.

Another possibility is a formal network of near peer mentors, where more senior students are assigned or suggested as available to provide advice, support, mentorship, etc., to novice women in CS majors. This is often done at Universities at the faculty level, where new faculty are assigned a more senior faculty member to be their mentor (e.g., Mullen & Hutinger, 2008). Several of the women in my study reported relying on self-identified peer and faculty mentors that provided additional social support through informal mentoring. Formal structures in place would have the potential to make an even greater impact.

In terms of practices that support retention, this study also offers a few implications for CS departments. Finding a job, which was not a requirement inside the department that my participants came from, was one of the crucial practices for their retention. This practice provided a positive experience for the women in my study, experience that helped them gain legitimacy, develop a sense of belonging and envision themselves in the field. As mentioned above, CS programs could adopt mechanisms that encourage women to search for a job early in the program, while at the same time serving as brokers who create bridges with those companies that other women already had a positive experience with.

Several findings from this study are not well-researched in literature. Practices such as the importance of establishing work-life balance, abandoning perfectionism and or learning how to find online resources, as well as taking classes that provide authentic learning opportunities were found to be crucial for the retention of women in this study. CS departments can do a lot to familiarize women with these practices and help them adopt them earlier in the program. The practice of abandoning perfectionism, for example is based on the understanding that CS is a skill-based field, where no one has the same skill set. Learning how to find online resources is a skill that involves a particular way of asking questions in specific online communities. Organizing a one-credit class for women in CS, or integrating lessons on how to adopt some of those practices into the Women in Engineering class, can be very beneficial for the retention of women entering CS.

Next, this study provides several case studies of women who succeeded in CS. In times where the number of women and female role models in CS majors is small, having

exemplary stories available is very important as they can provide the much-needed success stories to the women starting in the CS program. These case studies, or videos of women sharing some of the strategies they used to persist in the major, could also be included in introductory courses for women.

Finally, the cross-case study analysis reveals some potentially problematic areas inside CS departments, areas that could be better supported or utilized. For example, we learned that though there were several entry points into the major, not all of those entry points were supported equally by the department or the university. CS departments could invest more effort into supporting women who enter the program with some core and basic university courses done in another program and or while still in high school. Even though allowed to enter the program with such background, those women face additional challenges due to a course load that often consists of CS courses alone.

Another example are those courses that can be taken by students who are not enrolled in CS as their major. Such courses can be used as a recruitment place if designed to attract women's interest in CS. I found evidence that several women changed their major to CS after taking an enjoyable CS course to satisfy requirements in another major. In this study, for instance, we also learn that most women came into CS major with no prior programming experience. However, none of the introductory CS courses they took were designed for people with no prior experience, which is why they had a rough initiation into the program experience. Designing such classes (or special sections of existing classes) could benefit this major by contributing to retention of women or any other student with no prior experience.

As this dissertation shows, there are many ways to retain women in CS majors. Even though different women have different participation pathways towards retention, CS programs would benefit from training their faculty and students on the benefits of building a supportive community, while at the same time building special subcommunities at the periphery of the major to support women entering the program. In terms of practices, CS departments could include mechanisms that promote and broker finding a job early in the program, adapt their introductory courses to students with no prior programming experience, and or introduce women in their program to the practices that were identified in this study as practices that support retention.

Summary

This study adopted an innovative approach to studying retention of women in CS majors by focusing on women who persisted in this major, and by using an LPP in CoP theoretical lens, and methods, such as ESM and journey maps, that have not been used before when investigating retention of women in CS majors. The aim of such an approach was to gain new insights about the underrepresentation of women in CS education. As such, this dissertation adds empirical evidence to the body of literature on LPP in CoPs and it adds to the body of literature that strives to examine factors that support retention of women in CS majors.

In this section, all the findings are discussed by research question and in relation to prior literature and the theoretical framework. In this discussion, I highlighted areas that align with literature and theory, but I also identified areas that need further research.

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APPENDICES

Appendix A

Focus Group Protocol

FOCUS GROUP PROTOCOL

0. Tell me about the moment you realized you belonged in your CS major.

   (Prompt: When did you realize you chose the right major?).

1. Tell me about the moment you realized you will stick to CS as your major.
2. What do you need to do to become a recognized member of the community in your major? Who needs to recognize you? How does one become recognized?
3. How do you and your peers support each other? Please describe that for me.
4. What about other members of the community?
5. Now when you think of all the people surrounding you, who makes your CS major community? Describe it.
6. What kind of social rules are important to follow within your major?
7. How did the CS community in your major help you learn?
8. What resources particularly helped you grow within you major?
9. Did you ever consider leaving? If so, what helped you persist?
10. Have you ever felt like you were put in an unequal or marginal position where you do not really have access to all the resources and learning opportunities within your major? What did you do to overcome it?
11. Have you ever felt like there is some sort of hidden agenda/ tacit knowledge that everyone knew about but no one spoke about? How did you learn about it?
12. What do people need to do to persist/ succeed in a CS major? (Prompt: For example, how to you need to behave?)
    a. Do women need to do anything different from what you just described?

Appendix B

Journey Map Instructions

JOURNEY MAP INSTRUCTIONS

Take 10-15 minutes to think about and draw out your personal journey as an undergraduate student in Computer Science, on your way toward the completion of your degree. How would you describe the process you've been going through? Please take special care to focus on those moments that helped you learn the most, change as a person and most importantly, persist in your major.

Appendix C

Interview Protocol

INTERVIEW PROTOCOL

1. Please show me your drawing and tell me about your journey as an undergraduate student in Computer Science. (*Prompt: What helped you persist in that moment? What does this represent?)*

   Part two.

2. Now that we went through your drawing once, do you feel like there are some aspects of your story that you did not incorporate in your drawing, but wish now that you have? Tell me about them.

Community of Practice

3. When did you realize that you chose the right major? *Prompt: When did you realize that you belong?*
4. Tell me about the moments when you felt happiest about being a student in a CS major.
5. Who makes your community within your CS major?
6. Do you feel part of the whole CS major system? Tell me about that.
7. Are there any groups of people within the major that you exchange resources with? Tell me about them.
8. Who do you collaborate with most? Tell me about that.
9. Have you ever had an opportunity to observe or participate next to more seasoned members of your major? How did that influence you? What are some things that your CS peers do for you that make life bearable for you as you work towards your degree?

10. What kind of support have you received along the way?

Participation

11. Have you ever felt like you were put in an unequal or marginal position where you do not really have access to all the resources and learning opportunities within you major? What did you do to overcome it?
12. Who checked in with you to make sure you were progressing?
13. How much do teachers notice you in class?
14. Did you ever consider leaving? If so, what helped you persist?
15. How much of what you learn do you find useful for your future work in this industry?
16. Which experience was especially useful for your development throughout the major?
17. Who helps you believe in your expertise on daily basis?

Appendix D

SurveySignal (ESM) Questions

SURVEYSIGNAL (ESM) QUESTIONS

1. Type in your ID number, please.
2. Where are you now? Be as specific as possible.
3. Who are you with?
4. What are you doing right now?
5. On a scale 1-5, one being least typical and five being most typical, how typical is this activity for you?
6. On a scale 1-5, one being least related and five being most related, how related is this activity to your CS major?
7. How do you feel right now? Choose all that applies.

    a) happy

    b) excited

    c) surprised

    d) angry

    e) disgusted

    f) sad

    g) afraid

    h) ashamed

    i) nervous

Explain.

Appendix E

ESM Follow-Up Questions

ESM FOLLOW-UP QUESTIONS

1. On Day X, you mentioned going Y. Tell me more about that activity.
2. You mentioned X several times. How important is X for you?
3. How typical is doing Y for you?
4. How do you believe has the existence of Y (activity) or Y with person X influenced your persistence in the CS program?
5. Your completion rate is X, which is pretty good, but you've missed a few signals. Do you remember what you were doing when you missed those signals?
6. What did ESM, experience help you learn about your own routine?

Appendix F

Demographic Survey

DEMOGRAPHIC SURVEY

Name:

Age:

Year of study: Junior Senior Graduated _____

Full time/part time student:

When did you declare CS your major: (year) _____

Marriage status: single married divorced

Do you have children? Yes No If yes, how many:

Do you work? Yes Job Yes paid internship Yes other _____ No if yes, full time/ part time

Are you a native Utah resident? Yes No?

Where did you grow up? (i.e Logan, UT… Seattle,WA)

What of the following best describes you:

White
Hispanic, Latino, or Spanish origin
Black or African American
Asian
American Indian or Alaskan Native
Middle Eastern or North African
Native Hawaiian or other Pacific Islander
Other: _____

Appendix G

Recruitment Material

RECRUITMENT MATERIAL

Script

Hello - My name is ____(name)___ and I am an _____(title)____ from the Department of Instructional Technology and Learning Sciences at Utah State University. /Hi – My name is _(name)_____ and I am a doctoral candidate and a research assistant in the Department of Instructional Technology and Learning Sciences at Utah State University.

I am here to invite you to participate in a research study about persistence of women in Computer Science majors. You're eligible to be in this study if you are a female student enrolled in a CS major at USU who has reached an upperclassmen level of study (junior or senior standing).

If you decide to participate in this study, you will be asked to participate in three different activities. First, we will ask you to attend one focus group, where we will provide a compensation of $10 in the form of a gift card and some refreshments. This activity should last between 45 and 60 minutes. Next, we will conduct an interview with you for which you will be compensated with a $25 gift card. This activity will take 60 minutes. Finally, you will participate in a two-week long experience sampling where we will send you brief SMS surveys five times a day to inquire about your daily routine. Each of these surveys should take you less than two minutes per survey. The sampling experience will end with one 30-minute follow up interview. For this activity, we will provide you with a $50 gift card compensation.

All interviews and focus group will be audio recorded to facilitate data collection and data analysis. All recordings will be saved in a secured folder and deleted after data analysis is done.

Remember, this is completely voluntary. You can choose to be in the study or not. Everything you say will be considered confidential.

Do you have any questions for me at this time?

If you have any more questions about this process or if you need to contact me about participation, I may be reached at __(email)___.

___(name)_____, here present is my assistant. Please email her at ____(email)____. She will be conducting the interviews, so you may also email her directly to sign up for participation. Our office phone is ___(phone number)___. You can also call or leave a message there and we will get back to you.

Thank you so much.

E-mail

IRB#: 8701

Dear CS students,

My name is ___(name) and I am an ___(title)___ from the Department of Instructional Technology and Learning Sciences at Utah State University. I am writing to invite you to participate in my research study about persistence of women in Computer Science majors. You're eligible to be in this study if you are a female student enrolled in a CS major at USU who has reached an upperclassmen level of study (junior or senior standing).

If you decide to participate in this study, you will be asked to participate in three different activities. First, we will ask you to attend one focus group, where we will provide a compensation of $10 in the form of a gift card and some refreshments. This activity should last between 45 and 60 minutes. Next, we will conduct an interview with you for which you will be compensated with a $25 gift card. This activity will take 60 minutes. Finally, you will participate in a two-week long experience sampling where we will send you brief SMS surveys five times a day to inquire about your daily routine. Each of these surveys should take you less than two minutes per survey. The sampling experience will end with one 30-minute follow up interview. For this activity, we will provide you with a $50 gift card compensation.

All interviews and focus group will be audio recorded to facilitate data collection and data analysis. All recordings will be saved in a secured folder and deleted after data analysis is done.

Remember, this is completely voluntary. You can choose to be in the study or not. Everything you say will be considered confidential. If you'd like to participate or have any questions about the study, please email or contact Katarina Pantic, the Research Assistant on this grant at ____(email)____ or by calling ____(phone number)____.

Thank you very much.

Sincerely,

For questions of concerns about the recruitment process or this project, please contact:

Name

Principal Investigator

E-mail: ____

Flyer

(name of university)

Retention of Women in CS: Why Women Persist in their Major?

Research Purpose: This study is aiming to investigate the reasons behind female persistence in a CS major from the perspective of women themselves.

Who is Eligible to Participate? If you are a female student enrolled in a CS major and have already reached upperclassmen (Junior or Senior) level of academic standing, you are eligible to participate in this study.

Estimated time commitment: You will be required to invest approximately three hours of your time in this study. This time commitment is divided between three different events: a focus group meeting where you will also complete a survey, an interview and an experience sampling method, which will consist of brief survey text messages and a follow-up interview. Gift card compensation is available for each stage of this research.

For more information about this study, please contact the principal investigator in this study: Dr. ___(name)___, ___(email)___. To volunteer for participation, please call or email my assistant, __(name)__ at ___(email)___ or call our office phone at: ___(phone number)____

Appendix H

Daily Routines

DAILY ROUTINES

All ten women from this study participated in the ESM experience via SurveySignal technology, which provided a thorough overview of their daily routines. The following sections present frequencies and percentages for categories included in the ESM survey. It is important to remind here that these statistics refer only to the participants' waking hours (from 8am to 10pm).

Location

The first question of each ESM signal (*Where are you now?*) asked the participants to report on their location. This process resulted in a total of nine categories. Table H1 provides a list of the categories with descriptions and/or examples, as well as frequencies of their occurrence overall. They are listed from most to least frequently visited location. Figure H1 depicts the overall percentage each individual location appeared in the survey on average. As the last category "Elsewhere" translates into 0%, it has been removed from the graph in Figure H1.

As can be seen from Table H1 and Figure H1, only 18% of women in this sample spent their waking hours on campus, while more than half of their time (57%) was spent at home. Surprisingly, being physically at work took only about 5% of their time, overall. On average, about 12% of their time was spent in facilities related to achieving balance in life (e.g., social, religious and sport-related facilities) (see *Establishing Balance* category in results for RQ1 above).

Table H1

Participants' Reported Location during the ESM Experience

Location	Definitions and Examples	Frequency
Home	All references to participant's place of residence e.g., *at home, in my room, at my apartment, in my house* etc.	366
Campus	All references to physically being on campus, either in class or otherwise e.g., *in my physics class, CS3 class, at the library, at a Career Fair in the [student center]* etc.	117
Outside	All reports of commute e.g., *in a car, on the bus, I am outside [walking]*	39
Work	All references to participant's workplace e.g., *at my office, at work* etc.	33
Religion-related facility	All references to places where some type of religious activity was happening	28
Social	All references to going out or visiting people e.g., *at my friend's house, at a restaurant* etc.	23
Sport-related facility/place	All references to places where primary goal is to work out or do some type of sport e.g., *at the swimming pool, at a ski resort* etc.	23
Store	All references to places where you can shop e.g., *at Walmart, at a grocery store*	9
Elsewhere	Other	2

Company

The second ESM question (*Who are you with?*) asked the participants to report on their company. Analysis revealed nine categories of typical companions in their daily routines. Table H2 provides a list of the categories from most to least frequent, in addition to concrete examples and frequencies for each one. As most categories are self-explanatory, only a few definitions are provided. Figure H2 depicts the same information broken down by percentage. The last category ("on the phone") has been removed from the graph to secure ease of interpretation of the graph.

Figure H1

Percentage of Time Spent at Different Locations

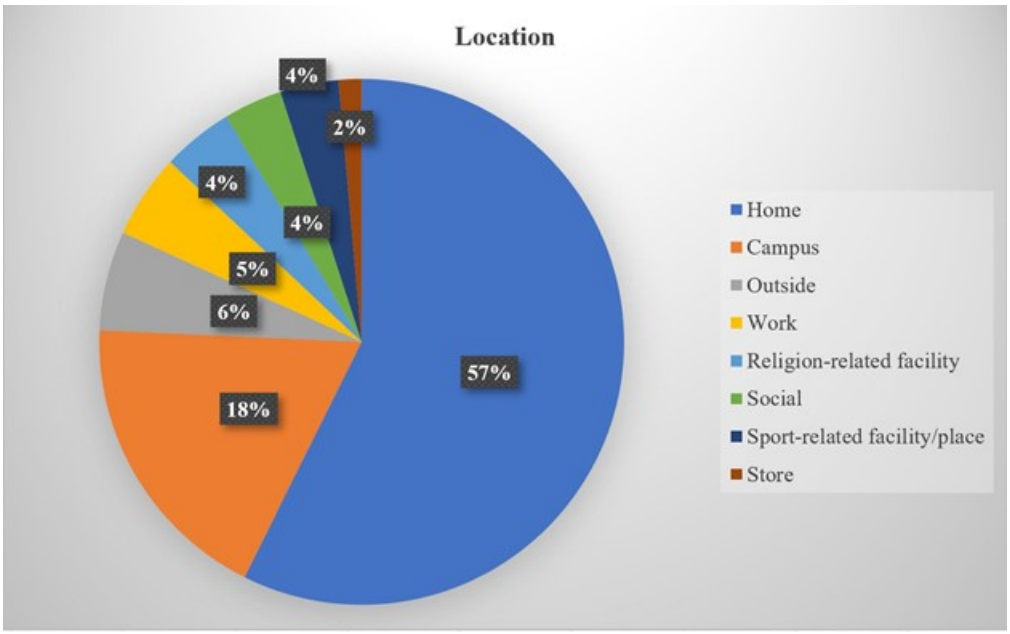


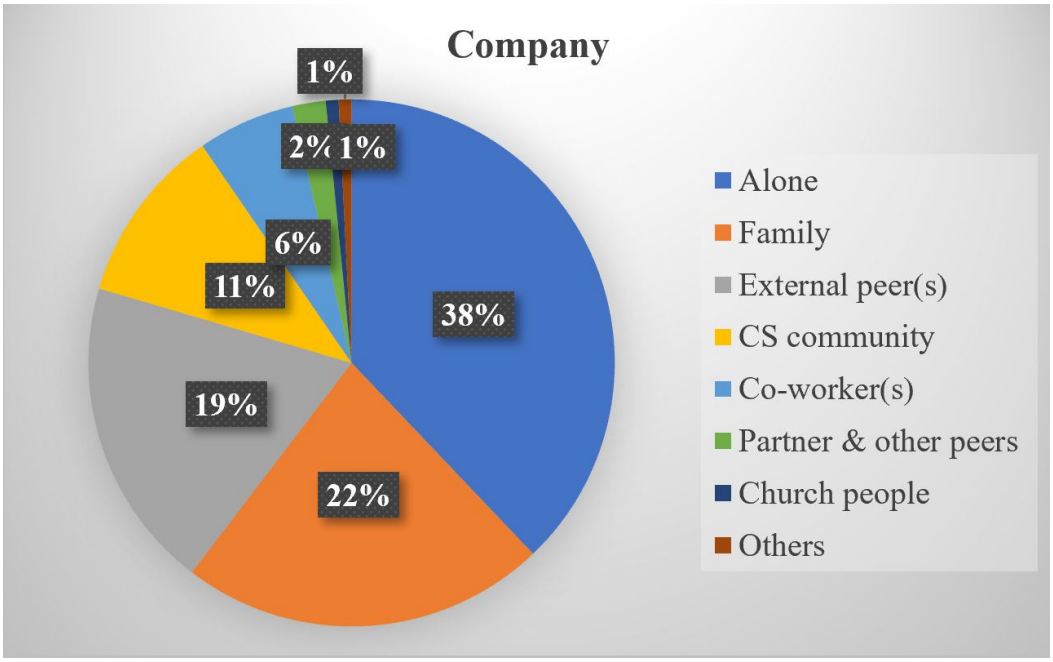
Table H2

Participants' Reported Company During the ESM Experience

Company	Definition and Examples	Frequency
Alone	e.g., *alone, on my own, no one* etc.	241
Family	This category includes parents, siblings, partners and other family members e.g., *my brother, some extended family members, my husband, my boyfriend* etc.	143
External peer(s)	This category includes roommates and external friends e.g., *my roommate, one of my roommates* etc.	122
CS community	e.g., *my classmates, peers, professors* etc.	69
Co-worker(s)	e.g., *my co-workers, one of my office mates* etc.	38
Partner & other peers	e.g., *my boyfriend and his roommates, my husband and his parents* etc.	13
Church people	e.g., *people from my church, the members of my congregation* etc.	5
Others	Other	5
On the phone	e.g., *I am with my mom on the phone* etc.	4

Figure H2

Percentage of Time Participants Spent in Company or Alone



As it can be seen from both Table H2 and Figure H2, women from this sample spent the majority of their waking hours (62%) in some type of company and about a third (38%) alone. This may be partially attributed to the fact that no one reported living alone. While most women had roommates, two lived with their husbands, and one lived with her boyfriend. People which were identified as their external communities (or outside the CS major communities) (see *Other Communities Women Belonged to* above) took 55% of their time.

Activities

The third ESM question (*What are you doing now?*) asked the participants to report on the activity that they were engaged in at the moment of receiving the signal.

Eight different types of activities were identified based on their similarity. All categories identified in this part of the analysis are listed and defined in Table H3, with added examples and frequencies for each category. Figure H3 provides an overview of percentage of time participants spent doing each activity on average.

After conducting the analysis of the women's answers to the third ESM question, I found that less than a third of their waking hours (28%) was spent doing school-related work, such as taking exams, doing homework or attending classes. Another third of their time (30%) was spent in *Establishing* (school)work-life *Balance* activities (see *Establishing Balance* theme under *Factors that Influence Retention* section above), such as relaxing (e.g., watching TV, playing an instrument and similar), socializing, working out, practicing a religion and/or volunteering. Weekly, work took about 8% of their time on average across all participants. However, it is important to mention that only nine of the participants had a part-time job, two of which had a 5-hour part-time job, and no one reported working on the weekends, which is understandable. The rest of their waking hours were spent doing everyday things, such as eating, commuting or doing house chores.

Typicality

I was further interested in investigating how typical the reported activities were for our participants. This question was incorporated as the fourth question in their ESM experience. Table H4 provides frequencies for each of these five items, while Figure H4 depicts the distribution of activities from least to most typical by percentage, and on average across all participants.

Table H3

Activities Participants Reported Doing During the ESM Experience

Activity	Definition	Frequency
Establishing Balance	This category includes activities that have been identified in RQ1 to contribute to (school)work-life balance, excluding school work, such as leisure time (e.g., *watching Netflix; playing the guitar; nothing really, just browsing Facebook* etc), spending time with friends or going out (e.g., *chatting, going to a restaurant/ movie* etc.), activities in relation to their religion (e.g., Attending the Institute, going to church, praying, reading the scripture, attending church-related events) and all sport- and fitness related activities (e.g., *going to the gym, skiing, doing yoga* etc.)	190
School work	All activities in connection to school work, such as attending class, doing homework, studying or taking an exam/quiz e.g., *I am sitting in class, I am doing my programming language homework* etc.	176
Other	Activities showing up once (e.g., *helping husband with homework*) or activities involving movement from A to B, getting ready, waiting (for a class to start)	79
Working	Self-explanatory; This category includes going to meetings	52
House chores	Self-explanatory e.g., *shopping, doing laundry, making dinner*	52
Eating	Self-explanatory	46
Waking up	All entries which suggest that the ESM signal woke them up	31
Volunteering	Self-explanatory e.g., *Teaching high schoolers about opportunities in the college of engineering*, *preparing a meal for 120 people, working on an extracurricular project for a local school* etc.	13

Figure H3

Percentage of Time Spent Doing Different Activities

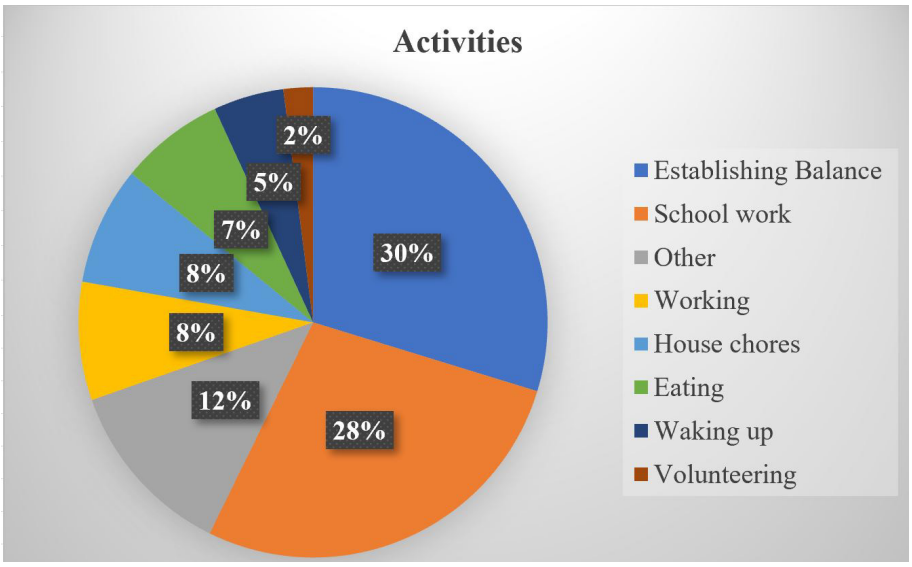


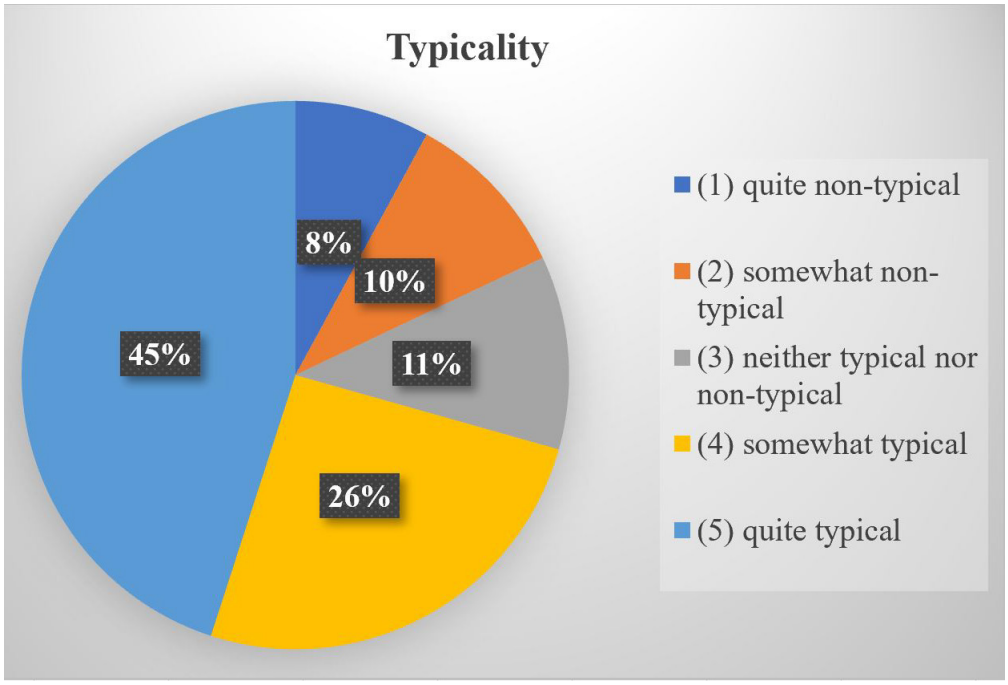
Table H4

Reported Typicality of Participants' Activities

Typicality	Frequency
(1) quite non-typical	51
(2) somewhat non-typical	64
(3) neither typical nor non-typical	73
(4) somewhat typical	164
(5) quite typical	288

Figure H4

Percentage of How Typical the Activities Were



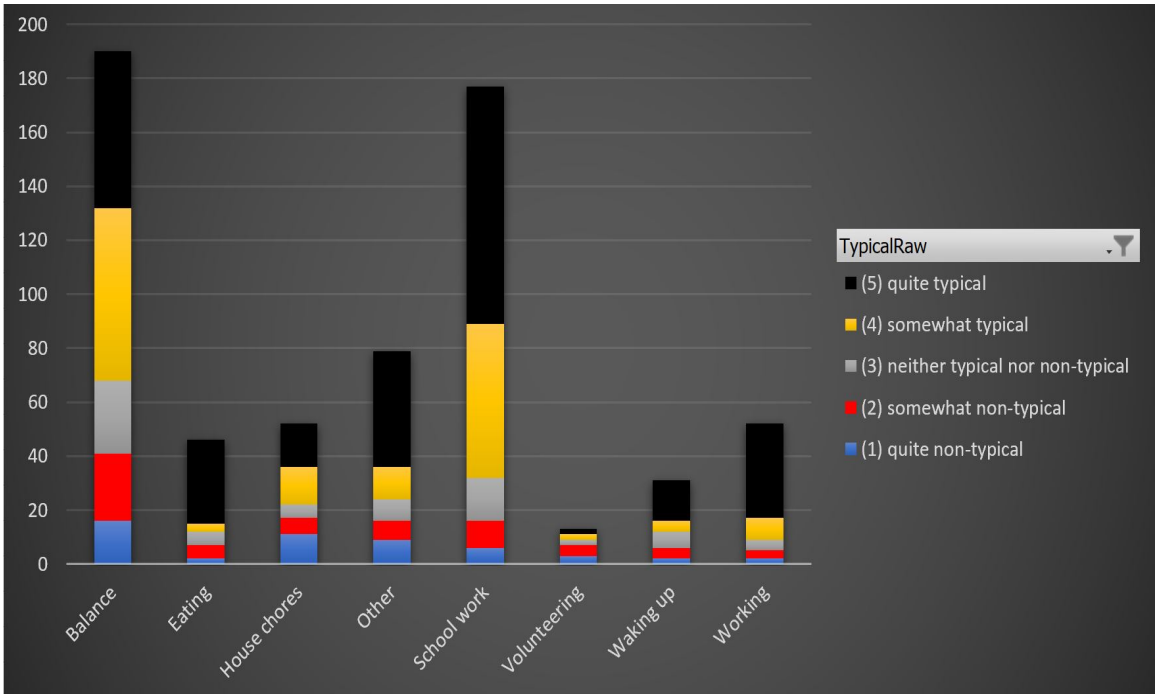
From this part of the analysis, I found that over two thirds of the activities (71%) were either quite (45%) or somewhat typical (26%) for the women in this study. To understand typical activities further, I created the chart represented in Figure H5, which breaks down each activity by how typical is was rated to be. Here we can see that all actions reported by the participants in this study are mostly quite or somewhat typical for them.

Relation to CS

Fifth ESM question examined how related the activities they reported were to their CS major. To that end, they were asked to report relationship on a 1-to-5 scale from

Figure H5

Actions Broken Down by Typicality



quite unrelated to *quite related.* The frequencies of their answers are provided in Table H5, while the percentage is depicted in Figure H6.

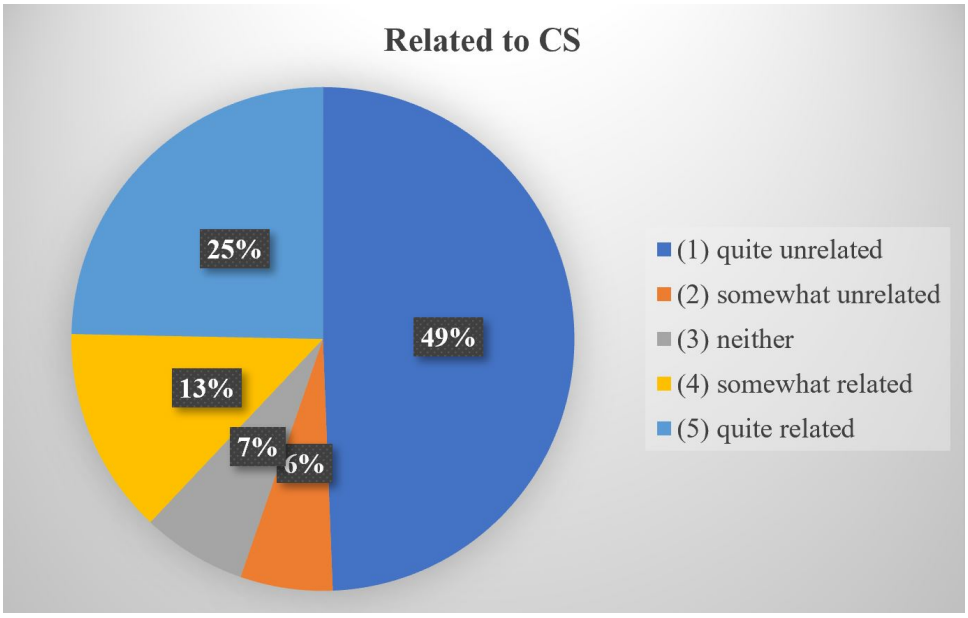
Table H5

Reported Relatedness of Activities to Participants' CS Major

Relatedness to CS	Frequency
(1) quite unrelated	316
(2) somewhat unrelated	38
(3) neither	43
(4) somewhat related	85
(5) quite related	158

Figure H6

Percentage of Time Participants Spent Doing Activities (Un)related to the CS Major



Interestingly, more than half the activities (55%) they did during their waking hours were marked as either "*quite*" or "*somewhat unrelated*" to their major, suggesting that students who persist in CS do not spend all their time studying, despite the general stereotype. Only about a third of their daily activities were reported to be related to their major (25% quite related and 13% somewhat related), which is similar to the amount of time they reported spending on *Schoolwork* and *Work.*

Affect

The final ESM question asked the women to specify how they felt for each time point (*How do you feel right now? Check all that applies.*) with an opportunity to explain the affect in a follow-up question (*Please explain why you feel the way you described.*). This question generated 791 reported adjectives, with 151 entries containing more than

one adjective. Realizing that the category "*other*" applied to too many entries (42% of total entries), I proceeded to recoding that item. This procedure mostly included identifying the emotion participants associated with their choice of "*other*" from their follow-up explanations. Upon recoding the *Other* category, identified affect was collapsed into four categories: *Positive, Negative, Neutral* and *Mixed.* Table H6 provides a list of those four categories with examples of adjectives incorporated under each one. The frequencies of categories are listed in a descending order from most to least frequent. Figure H7 depicts the same distribution of affect by percentage.

Table H6

Participants' Reported Affect during the ESM Experience

Affect	Definition	Frequency
Positive	e.g., *happy, excited, content, calm, determined* etc.	312
Negative	e.g., *tried, frustrated, bored* etc.	208
Mixed	e.g., *excited and afraid, happy and nervous* etc.	67
Neutral	*neutral*	53

To understand which emotions were related to which activities, I created the chart represented in Figure H8 which breaks down each activity by affect. From this visual we can see that no activity brings up exclusively positive or exclusively negative emotions, but that negative and mixed emotions do somewhat dominate *Waking up, School Work* and *Work,* while other activities are mostly associated with positive and neutral emotions.

Figure H7

Percentage of Reported Affect During the ESM Experience

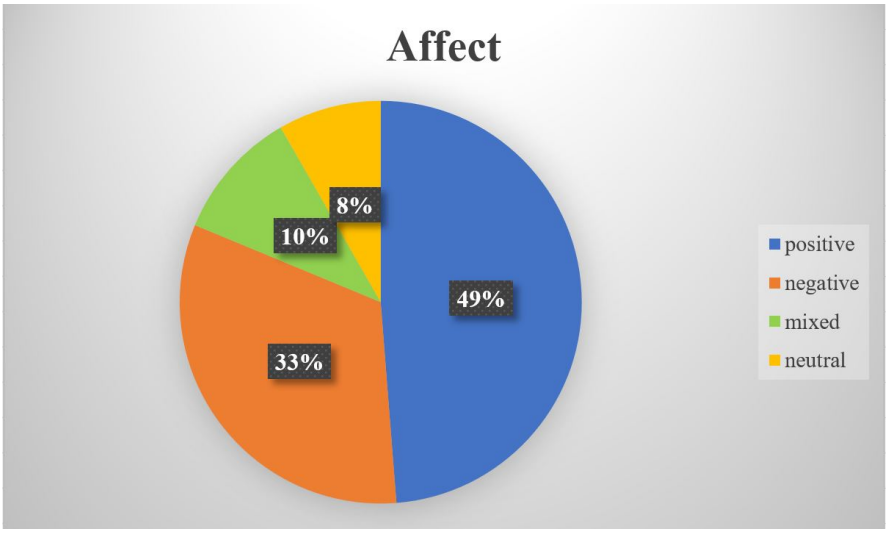
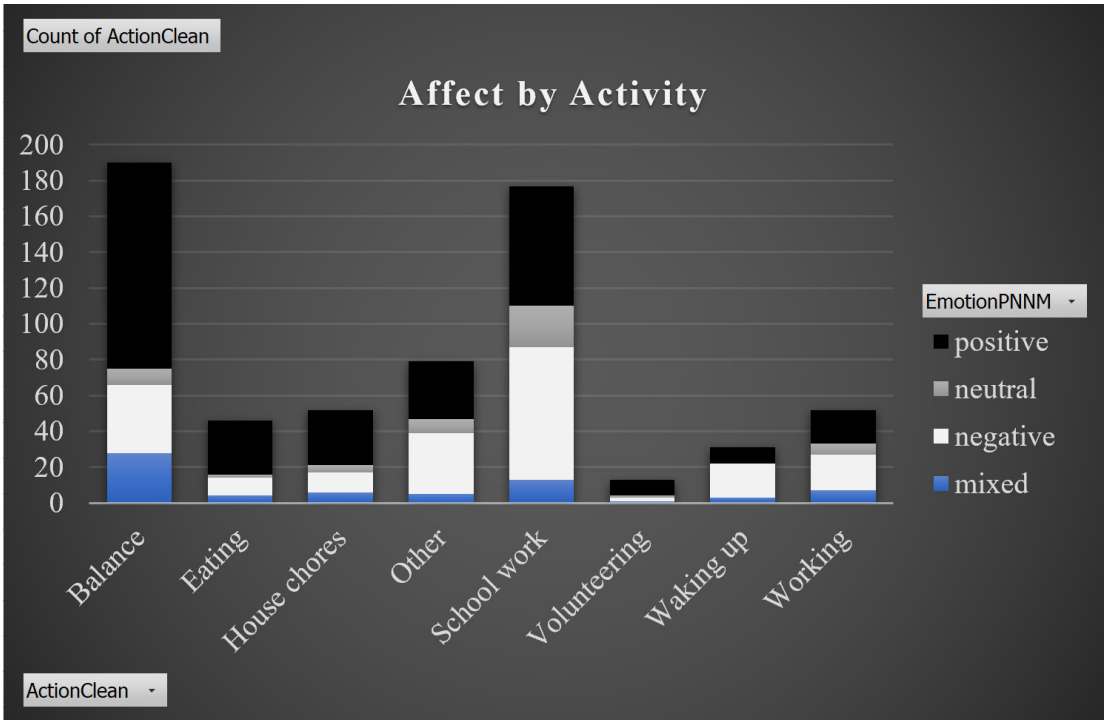


Figure H8

Affect by Activity



Appendix I

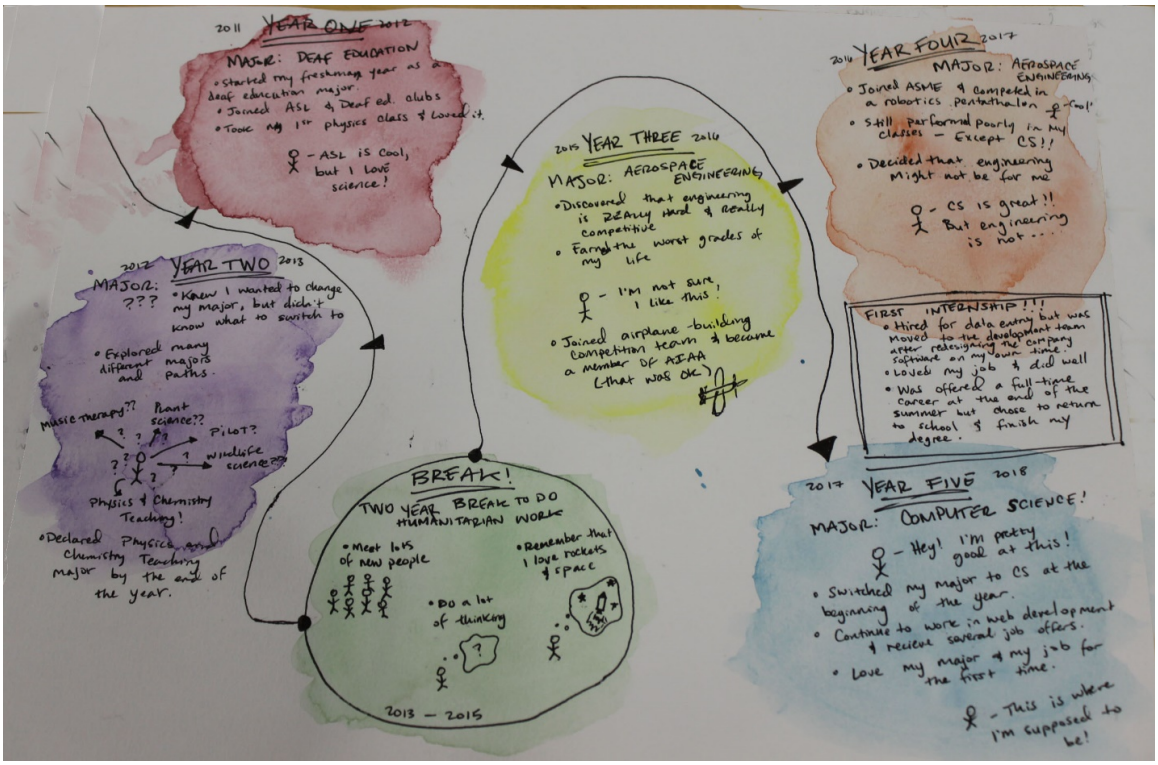
Remaining Case Studies of Individual Journeys

Case Study #6: Haley: The Outsider Looking In

Of all the participants in this study, Haley had the most unconventional entrance into and journey through the CS program. For that reason, she refers to herself as the "outsider looking in." When we met, she was a Junior in CS, but it was her fifth year studying at the same university with CS being her forth declared major. Her journey map (see Figure I1), therefore, looks like a road that is weaving through "villages" of majors she tested and dropped before eventually discovering and enrolling into CS. When explaining why she drew her map that way, she said she "[could]n't really talk about why [she was] in computer science unless [she] talk[ed] about where [she] came from." She

Figure I1

Haley's Journey Map



felt that though she did not finish any of those majors, they all contributed to who she was and made her "uniquely qualified." This last piece made her really excited about her future career because she believed such background would open a lot of doors for her.

Before she declared CS as her major, Haley had not only changed several majors, but she also spent two years away from college doing humanitarian work. Her undergraduate studies started in Deaf Education, but she soon realized that she preferred learning science. The following year, she explored several majors through classes and activities, and ended up changing her major to Physics and Chemistry Education. At that point, however, Haley took a 2-year leave of absence to do humanitarian work, which helped her re-examine her interests and academic choices. That is when she realized that a lot of her passion lies in "planes and stuff that flies." Even though pursuing this passion signified another change in major, Haley decided it was better to spend more time in school than worry about her choices later in life. Upon returning to the university, she enrolled into Aerospace Engineering only to find it far from what she expected it to be. While teamwork and designing were "exciting," she did not "necessarily enjoy [the classes]" she took, which was surprising to her as she was interested in this topic for as long as she could remember. What is more, instead of getting easier with time, the classes only got harder and she started "getting the worst grades of [her] life." At the same time, she had her first CS experience. In addition to doing "a little bit of the coding for [a] robot" at a robot pentathlon, Haley took her first CS class.

> That was a huge break from engineering for me. I loved CS. It came easily. I easily got an A. I just… I loved everything about it. The homework was completely different. Coming out of that class, I knew I liked computer science. (Haley, interview)

As we can see from this quote, a CS class provided a completely opposite experience for Haley than her Aerospace Engineering classes. She got the impression that CS was both enjoyable and easy. That same summer, she got an internship with a software group where she was initially hired as a data entry person, due to her limited programming experience. Upon using their software, which she perceived as "clunky," she proceeded to redesigning it in her free time. After proposing a prototype to her management, she was moved to the development team inside the company. To work on the development team, however, Haley had to learn five different programming languages in a couple of months.

> There was a huge learning curve to it, and I made a lot of mistakes, but I picked up those programming languages in about two months and got to start coding for the designs that I had created, which was really cool. I got to see that program from start to finish. (Haley, interview)

In other words, unlike other students who first took classes inside their major and then proceeded to working in the industry, the majority of Haley's initial CS learning happened at work. From there on, her learning of CS never stopped. The company ended up offering her a full-time job, but she decided to work part-time and finish her degree first, which was still Aerospace Engineering. However, as the Fall semester resumed, the troubles with engineering classes continued. She had a feeling that she was failing, and she found the subject matter uninteresting and "way over [her] head." In other words, unlike programming where she was able to learn a lot and learn fast, engineering was not going well for her. She neither enjoyed it, nor was she enthusiastic about being in it.

> There was a part of me that was saying, "Push through this. Just get what grades you get and graduate." Then there was this other part of me that said, "I'm really good at CS, and I know I'm good, and I know I enjoy it." That's the point when I

> went, and I talked to an academic advisor and said, "How long is it gonna take me to graduate if I do move to CS?" (Haley, interview)

Haley's decision to change her major to CS was based on careful consideration of pros and cons for both majors. She realized that it would take about the same amount of time to finish either of the two degrees, but she also believed that she was more likely to fail classes in engineering, which automatically meant engineering would last longer. Therefore, at the beginning of her fifth year at the university, Haley changed her major one last time and declared CS as her major. According to her, this change placed her in a "weird spot" (i.e., she felt like "an outsider looking in"), as she had to take both introductory and advanced CS classes at the same time. On one hand, she felt that introductory classes were a "waste of [her] time," because a) she was ahead of the class and yet b) she could not ask the "tough" questions because the rest of the class was struggling with the basics. On the other hand, she did not exactly have a sense of belonging in her advanced classes either, as a) everyone knew everyone else, but no one knew her, and b) those classes made her realize how much she missed by not attending classes before.

> "I'd all of a sudden get paired with juniors or seniors, and this was when I was definitely still learning and felt behind. And so, they'd be like, "Oh, well, this, this, and this," and I was like, "I have no idea what that is, but I can't really tell you that." (Haley, interview)

In other words, despite her extensive programming experience, Haley never learned to program in a conventional way and she lacked the vocabulary needed to communicate with her peers. Lack of vocabulary prevented her from participating fully in the conversations happening in her advanced classes. She was also not able to help her peers

debug and troubleshoot, despite doing the assignments easily herself. Problem-solving and code inspection was never part of her job description before, exposing her to more explicit learning opportunities. Once enrolled in the major, she discovered areas in which she could grow as a professional, all of which was now possible in her new major.

As a consequence, Haley felt that even after declaring her major, the majority of her learning happened at work, where her main opportunities for collaboration with and learning from more experienced programmers were. Despite her unconventional journey, Haley was satisfied with her final choice of major.

> In CS, everyone codes in their own style, and it's fine. You can break your problems down into small problems and say, "I'm gonna work on this chunk, and then I'm gonna work on this chunk," and eventually you'll get the whole puzzle figured out. I don't know. It's a lot different, and I love it. (…) I've discovered that I'm good at this. I love it. It's where I'm supposed to be. (Haley, interview)

As it can be seen from this excerpt, Haley saw CS as a major that was good for her, as she both enjoyed it and excelled at it. Nevertheless, Haley believed that her whole educational experience "built on each other" and made her who she was. As an example, she said that having an engineering background where she learned how to look at problems and design solutions for them, contributed to her being able to notice software problems at her internship. Noticing a problem led her to propose solutions, which again initiated a whole set of other changes in her professional and academic life.

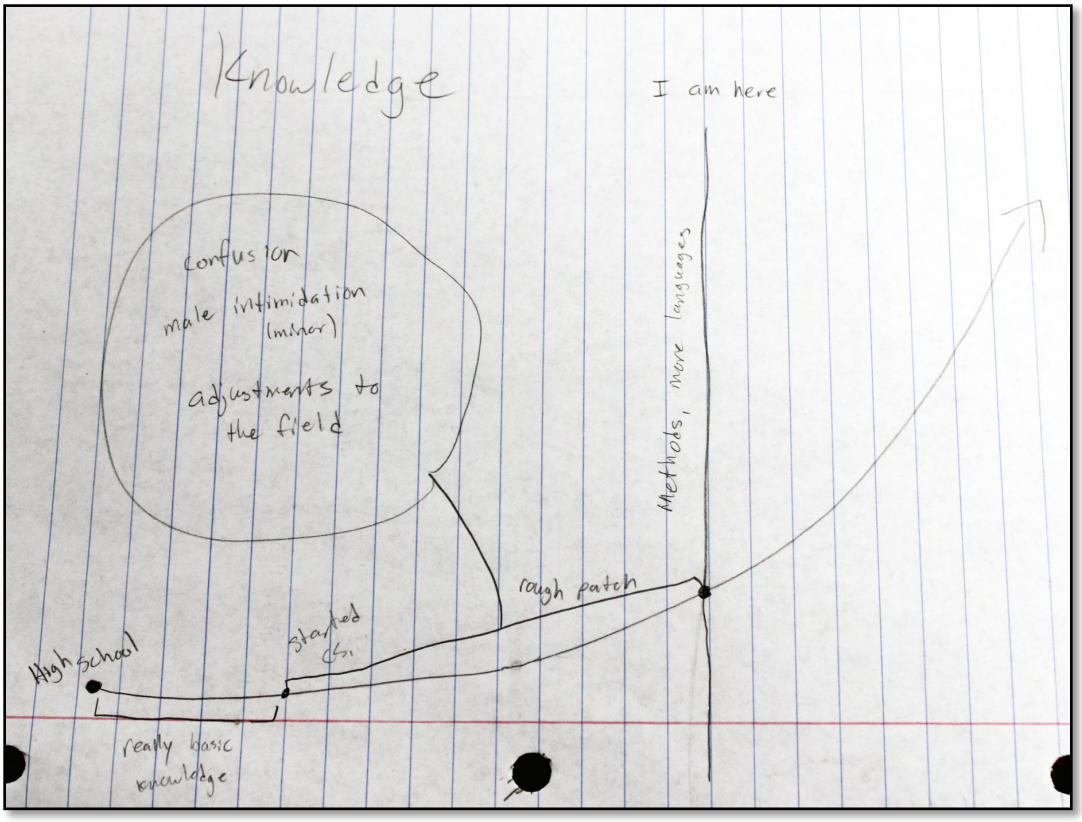
Case Study #7: Adele's "Lone Wolf" Journey

Adele drew her CS journey as "an exponential curve going [up] in terms of knowledge and confidence" (see Figure I2). In other words, she believed that her persistence in CS was a function of two variables: confidence and knowledge. She was

convinced that her confidence in CS did and would naturally grow as she built more knowledge in CS. The spot where the curve intersected the y-axis represented the moment of the interview. She was a Junior in college with a major in CS and a minor in mathematics, when I interviewed her.

Figure I2

Adele's Journey Map.



Adele started college as part of the Honors Program at the university, which she liked because it allowed her to meet other "nerdy" people like herself. She also got engaged in several knowledge building clubs, such as the Linux Club, and the Free Software Club. At the same time, she had a part-time job "ref-ing" basketball for the

university. Academically, she was also interested in psychology, in addition to CS and math. For her, the struggle had never been about persisting in CS, but about finding a way to incorporate all her academic interests into her studies.

Adele got introduced to CS in high school, where she took a basic JavaScript coding class. After that, she started tinkering with programming and even though, in her opinion, she explored "really simple stuff," she "got into it deep enough" to realize "[CS] was something [she] wanted to do" for the rest of her life. As she took most of her general college-level courses in high school, Adele started college as a Junior and dedicated that whole year to catching up with her CS requirements. During the first semester, Adele took two CS classes where she focused on "understanding what computer science was" and learning another programming language. She described this period as "a rough patch."

> Most of the time, I was just confused. I'm a self-teaching person a lot, and I just don't think the professors were teaching, so I would teach myself. And sometimes that would be more confusing than the professors actually. (Adele, interview)

From this excerpt, we learn that Adele's entry into the major, similar to Jane's, was rough, despite her prior experience with programming. Her approach to learning, "self-teaching," was not always helping her develop deeper understanding of CS concepts during her first university semester. To overcome her struggles, Adele started relying on social support for the first time in her life. However, self-teaching remained her preferred and primary learning style, the main reason being that she felt working in study groups or with partners was distracting and it "[took] away from her learning" experience. She felt that if she worked on something long enough, "[she] [could] normally end up picking it

up," which is what she focused on doing. This "lone wolf" approach, as she referred to it, was crucial to her persistence. According to her, more knowledge led to more confidence in CS and there was no way around it, but to build more knowledge.

Additionally, however, Adele also relied on certain aspects of social support. Unlike some other participants in this study who heavily relied on social support, Adele's visits to the tutor lab, the professors, and/or an occasional peer were "periodical, but not frequent." From the professors and peers, she appreciated receiving pointers and insights into the major, she also appreciated learning about the CS profession, such as what languages were good to know or what clubs she should be joining. She reached out to the tutors more regularly, but only when she was "really stumped and frustrated."

> I found that the tutoring center helps a lot more [than peers], so I go there every time, if I need anything, or if I'm just really confused on the concept or what I'm supposed to be doing. (Adele, interview)

That is to say, the tutors helped her understand concepts and or assignments that she was struggling with, but only on occasions when her "lone wolf" approach was not working out for her. Once she learned "what computer science was" and she got a "sense of what it would be like to actually work in the field," she felt that she was more adjusted to the major and really appreciating the variety of learning opportunities her major had to offer. During her second semester, for example, she took a class where the professor had them "work off other people's code" to help them understand how it was when you work in the industry. In another class, she felt that she learned how to "think like a programmer" and or how central problem-solving was to programming. These and similar learning opportunities helped her understand "how to adjust to the field," while everything she

went through was perceived as a stepping stone towards becoming a CS professional, which really helped her build her confidence and sense of belonging.

The only minor challenge she reported, in addition to being overwhelmed with some initial classes, was feeling intimidated by the number and attitude of men in those same classes. That quickly stopped bothering her, however, as she remembered this topic being discussed at orientation, where they were warned that some people would try to show off, when in reality they do not know much more. As a strategy, she decided to focus on the positive people.

> Not all of 'em are like that. I just find guys that aren't as arrogant about their knowledge or superiority. I study with them or sit by them in class. (Adele, interview)

In other words, towards the end of her Junior year, Adele still used social interactions to her advantage – to expand her understanding, get insights and or do classwork. She felt that she had "a lot to grow or gain," which was represented by the blank area on the right hand of her map. However, she believed the present moment to be "the hardest part of the major" and that it can only go downhill from there.

> Once I get more familiar with the concepts and the languages, the more I can build on it, and the faster I'm gonna learn, the faster I'll be able to catch on and do better. (Adele, interview)

In other words, one of the main persistence factors for Adele was her firm belief in the power of knowledge. As a consequence, she worked hard to expand it. Even though she struggled through her first CS courses, she never doubted her choice of major and she never thought of changing it.

Another big factor influencing her CS persistence was a balance of physical

activity, academic work and spirituality. She had a theory that if she focused equally on all three aspects of her life, that is, went to church, "[did] well on homework" and remained physically active, then she "[could] succeed in what [she] wanted to succeed in," which in this case was her major. Physical activity was of particular importance.

> There is something about exercising. It releases endorphins that kind of bring you back to the present. So, you are less worried. (Adele, follow-up interview)

As someone who had played basketball and soccer for a long time, was an avid snowboarder, and was still serving as a basketball referee, Adele had a lot of faith into the power of exercise. She reported feeling that "every time [she] moved" she released "energy, tension, [and] stress." For that reason, every time she was struggling with homework or studying, she would take a workout break to "re-center" herself. Similarly, she was a big "advocate" for sleep.

> Your mind needs to recuperate. So, sleeping is the best way to do that naturally (…) Sleep also, it's been scientifically proven, helps you remember things that you've learned on the previous day. So instead of trying to cram all night and remember it for a short amount of time, you can actually keep a long-lasting memory and comprehension if you sleep [regularly]. (Adele, follow-up interview)

Case Study #8: Savannah Journey of Parallelly Pursued Passions

When I met Savannah, she was a Junior in CS. Though she never physically switched majors, she deliberated between two majors for a while. She even took courses in both majors parallelly for as long as she could. Her original desire had been to study Computer Engineering (CE), as she believed them to be the "smart"-est people. That plan was modified by a CS scholarship she received after winning second place in a national computing competition for women. The scholarship came with a condition – she had to

declare CS as her major. At that point, she decided to use the scholarship, "pretend" to study CS for a while (that is, take both CS and CE classes), and switch majors when the time was right. However, as she progressed through the CS major, CS classes became more appealing to her.

> As I was going through the classes, I found that I really liked the Computer Engineering stuff (…). But, when I was in my Computer Science classes, I felt like I was very good and like it super was for me. (…) When I looked at the higher-level courses, that was really what made my decision for me. I was like, would I rather learn about advanced signals or would I rather learn about neural networking. And you know, there's a little bit of like, "oh, this is cool" [effect]. (Savannah, interview)

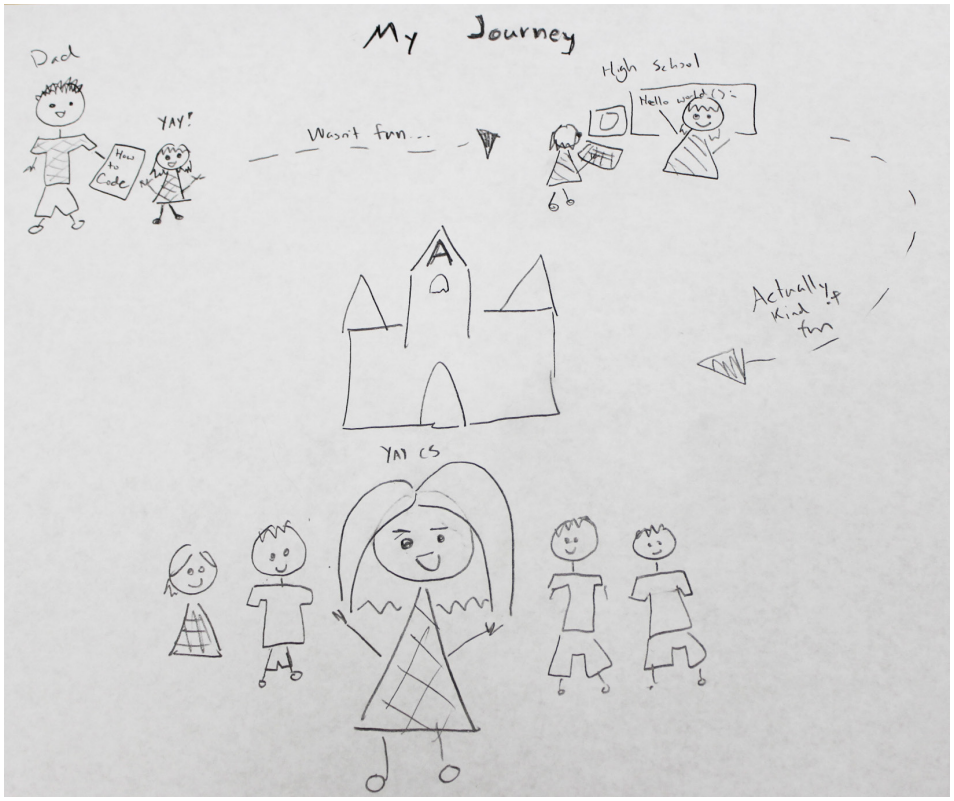
In other words, when it came to deciding between CS and CE, the appeal of future CS classes made Savannah stick to her CS major. Apart from having the dilemma between CS and CE, Savannah never doubted her choice of major, neither did she seriously consider leaving it. Her journey map (see Figure I3), though focused on the CS journey "in general," was interwoven with snippets of her CE experiences.

Savannah's father, similar to Shelby's, served as her broker into the CS community. Seeing that she enjoyed "playing video games almost before [she] could read," her father, whom she described as someone who was always "excited about technology," got her a "how to code" book and an old laptop that ran Linux, when she was still in middle school. Though initially excited about the idea (this is depicted by the "yay!" exclamation in the map), she did not find the experience "very fun," as she did not "instantly make" video games:

> I know now that wasn't really programming. That was navigating a command shell, but I did start on that and I thought it was exciting at first until it just lost traction. (Savannah, interview)

Figure I3

Savannah's Journey Map.



As we can see from this excerpt, the reason why Savannah did not like her first "programming" experience was because it was not as creative as she thought it was going to be. She was hoping to make games and write programs, but instead she learned more basic things about computing. This same experience, however, turned out to be "really useful" during her CS studies, as it gave her an advantage and allowed her to skip a class.

At the same time, the engineering experience she received in middle school was "really positive" and hands-on, which she experienced as "fun." She received that experience in an engineering-focused middle school, where she had engineering classes on regular basis and learned about resistors, used drill saws, designed "mechanical arms"

and “water pressure systems” in CAD software and similar.

In high school, Savannah took another programming class. This time she learned about Web Design, which she found to be “cool,” “nice and relaxing.” The following excerpt is about how she felt in one of those high school programming classes.

> I found it was actually really relaxing. I could go in, and if I was stressed out about something, I would have to focus on the problem. I would have to be thinking of these algorithms and I would kinda forget these other things that were happening. It was almost like this nice other place in my head. (Savannah, interview)

In other words, programming soon became a place of comfort for Savannah, “a fun thing that [she] liked” doing regardless of what was going on in her life. At that point, she was already thinking about college and she decided that she “wanted to be doing something with technology.” However, as mentioned above, her first choice was CE, not CS. In addition to having more engineering hands-on experience, she was also drawn to CE because she perceived CE people as “smarter.” However, as mentioned above, a CS scholarship landed her in a CS major, always wondering when would be a good time to switch. As a “religious” person who highly valued motherhood, she also had thoughts about which of these two careers would be better suited and more flexible for a future mother. From that angle, CS felt like a major that could provide her with the flexibility she needed to take care of her future family. In addition, she felt that a CS degree was much more adjustable to any desired lifestyle, overall.

> I think [with] computer science—I saw a future—with any choice I wanted to make in the future, I could find some lifestyle that I felt like a CS degree could help me achieve that lifestyle. It was almost like I could push my future desires and make myself happy no matter what by pursuing CS rather than engineering. (Savannah, interview)

As seen from this quote, even though initially split between these two majors, Savannah soon started perceiving CS as a more flexible and more suitable major for her, which made her persist in its completion. In addition, she was thriving in all her CS classes. As a result of prior programming experience, she "felt like [she] was one of those students who was a little bit ahead coming in."

> I don't feel like I've excessively struggled. Like there have been struggles. There have been classes where I haven't quite made the final project work and stuff like that, but I've never felt like the students are here and I'm here, like I hear some CS students saying. (Savannah, interview)

In other words, in terms of prior knowledge and experience Savannah started on even keels with her cohort. Unlike some other women in this study who struggled with the subject matter especially during their Freshman year, Savannah never doubted her ability to succeed in this major. As soon as she enrolled, she got permission to skip the first CS class, and started the next one with no subsequent regret. Throughout her college experience, she reported always feeling "comfortable" and never "too overwhelmed." She liked learning "cool new" things and she felt like she "made a lot of friends," which is depicted by a drawing of her and her friends at the bottom of her journey map. It is these two factors that influenced her persistence in the major the most. She not only found joy in the subject matter, but she also received a lot of encouragement and legitimacy from her "friends," one of which was her boyfriend.

In addition to her overall satisfaction with the major, Savannah had several internships which both "supplemented [her] classes" and boosted her self-confidence in terms of CS. She got her first internship at a big tech company, where her father worked. Next, she got a job at a big software company. These internships were "fun" experiences

for her, as they "gave [her] confidence that [she] can succeed" in the field. According to her, the two main reasons why the internships were so beneficial were: the social aspect of both jobs (e.g., she found mentors in other more seasoned members) and their ability to help her realize her own ability to learn.

> I felt like I identified with these people and I can fit in, not just in college but after college. Like I can be in place with people I like and be working on things and being productive but also—it's not like I'm just in a cubicle, the standard stereotype, all day. You know, you go to meetings and you have friends and stuff. And the other thing was, every single time, I had to learn something completely new, but I never felt pressured about it. I guess it made me feel like, "oh, it doesn't matter where I go in industry, like if it's something I'm interested in, I can learn it. No matter how out of my comfort zone it feels like, it's something I can do. (Savannah, interview)

In other words, internship opportunities provided her with the necessary real-life experience she needed to both understand the real nature of CS industry jobs, as well as how good she would be at adjusting to that type of a workplace, both personally and professionally. She was not only legitimized by her older colleagues, but she also perceived herself as a productive member of the community. Interestingly, the same way she emphasized the social aspect of her studies as her main source of motivation to go to classes, that same social aspect at work was also something she recognized and appreciated.

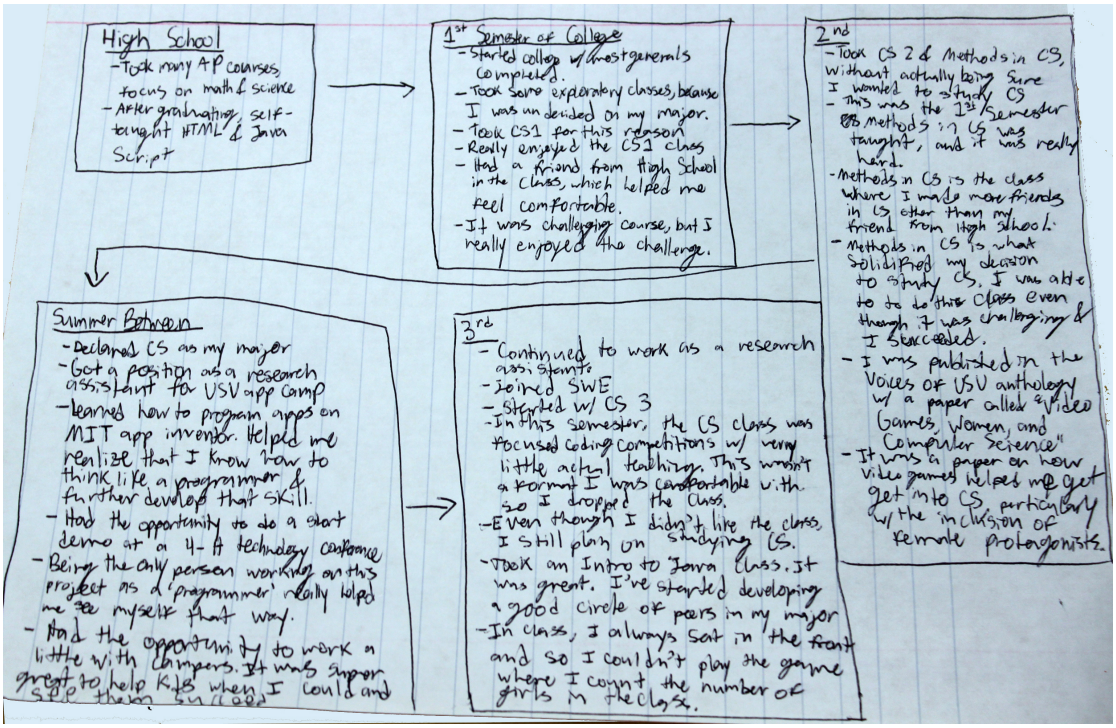
Case Study #9: Erin's Journey of Slowly Tested Waters

Erin's journey map was drawn as a chart of bullet-pointed notes on those experiences she considered to be the most valuable to her retention in the major. She anchored her experience in five different time periods (high school, first three semesters

in college and the summer in between Freshman and Sophomore year). She organized her map chronologically (see Figure I4).

Figure I4

Erin's Journey Map



Even though Erin was in her forth semester in college, at the time of the interview she was already a Junior in college with a declared major in CS. Like some other participants in this study, she took many math and science-focused AP classes in high school. Therefore, when she started college she had most of her "generals completed." In high school, she self-taught herself some HTML and Java Script, starting CS college classes with some programming experience under her belt.

Despite having some programming background and a father who worked in

programming, Erin did not declare her major in CS right away. As a matter of fact, she spent her first year at college "undeclared" telling herself that she "didn't know what [she] wanted to major in" when in fact she was just "fooling" herself, according to her. In other words, she knew that she wanted to do CS, but was hesitant hearing it may turn out to be too hard.

Across her whole experience in college, Erin's retention in her CS major depended on peers she studied with and received emotional support from. For example, one of the things that made the first CS class "fun" and less "scary" for her was having a friend from high school in the same class. She sat next to and did homework with her. According to her, this first CS class in college was "challenging" but ultimately enjoyable, so she decided to take two more CS classes. This is when she started reaching out to other people.

> I was really uncomfortable in the class itself actually 'cause I did not know anybody in my section of the class. But, I knew a bunch of people in the earlier section, so I worked with them on homework and stuff, 'cause it was just a very hard course. (Erin, interview)

As we can see from this excerpt, having friends in class that she can form study groups with was important to Erin. This theme repeated itself throughout her college education. She even reported dropping a class in which the social aspect was not allowed, because she did not like the fact that "it was trying to cut [her] off from the people [she] could usually ask for help." In one of those classes, she mentioned meeting and working with peers who were "further in the program" than her. In particular, she really appreciated meeting two women, one of whom ran Hack[University] coding competition. She perceived them as "cool," while working with them made her feel "less like the odd ball"

in this male-dominant major. In addition to working with her classmates, she also lived in the same dorm with a lot of other CS students. Living "in the same place with all your study buddies" most of which were "really fun to hang out with" was something she found to be both helpful and enjoyable.

Another group of people she reached out to in the beginning of her experience were the tutors in the tutor lab. Interestingly, knowing some of the tutors personally from either her dorm or through her roommates helped her rely on that resource more than she normally believed she would.

The most influential person throughout her studies, however, had been her father, who did "programming for a living." She mentioned his influence several times throughout her interview. For example, he was "excited [about her] learning" CS and he regularly checked in with her to make sure she was progressing well, especially if she had a class she was "struggling with." She also regularly called him for advice when her code was not working. When asked who helped her believe in her own expertise, she said that is was "definitely" her Dad.

> …really what he does when he is helping me is he takes a back seat and I just talk to him and I say this is what I am thinking about and he can kind of say "ok, if this is what you are thinking about, then look up this!" and so he definitely helps me with that but it's still me who is doing all the programming. (Erin, interview)

Erin here described how her exchange with her father normally looked like when she had a problem with an assignment. Her father's "back seat" approach did not prevent him from listening to her or providing her with advice, but he never did more than that. What is more, she felt that his approach empowered her to become an independent and confident programmer, a programmer with "skills." Nevertheless, she never mentioned

her father being the one who encouraged her or inspired her to pursue this major, which was the case with some other participants. In addition to her father, Erin also mentioned her mother as crucial for her persistence in the major.

> I definitely like to talk things out with my mom (…). Just kind of like lay it out, cause once I can kind of see it, once I can kind of see what my thought process is, I can kind of be like "that's not really productive or helpful!," but when it's just in my brain, I am not that good at it. (Erin, interview)

In other words, verbalizing frustrations and thoughts about problems with her mom helped Erin get out of her head and refocus on her studies. She was aware that problems felt bigger when left unspoken, which in return was not "productive" for her or her satisfaction with the major, so she made sure she reached out to her mother whenever she needed to "talk."

After her first year in college, Erin decided to declare CS as her major. At the same time, she got a research assistant position at the university where she helped develop a summer camp programming curriculum for middle school youth. Considering that she worked with block programming for the first time in her life, this experience helped her "realize that [she] knows how to think like a programmer" even when the language was new. This in turn helped her believe that she can succeed in this field, while all of it together additionally increased her CS "confidence."

Interestingly, like many other women from this study, Erin also had a minor in a CS-unrelated field, American Sign Language (ASL). In a way, these two together provided the balance that she needed.

> I do this thing sometimes when I am in CS classes where I count how many girls are in the class, which is not like a very good morale boost for me. Ever. (…) I do it in my ASL classes as well. But like I do it for boys 'cause there are always less

> boys in sign language (…) And so… I like to say that I even myself out when I do that. Because in CS I am surrounded by mostly boys, but in sign language I am surrounded by mostly girls. (Erin, follow-up interview)

Through her interviews, Erin mentioned feeling like the odd ball, as she was one of few women in CS. For that reason, but also because she "liked" ASL, she took it as her minor. Having a major where she was a minority and a minor where she was the majority helped her be less self-conscious overall. Finally, to reduce the amount of stress in her major, she made conscious efforts to have hobbies, such as swimming or playing the melodica, and/ or organize game nights with friends.

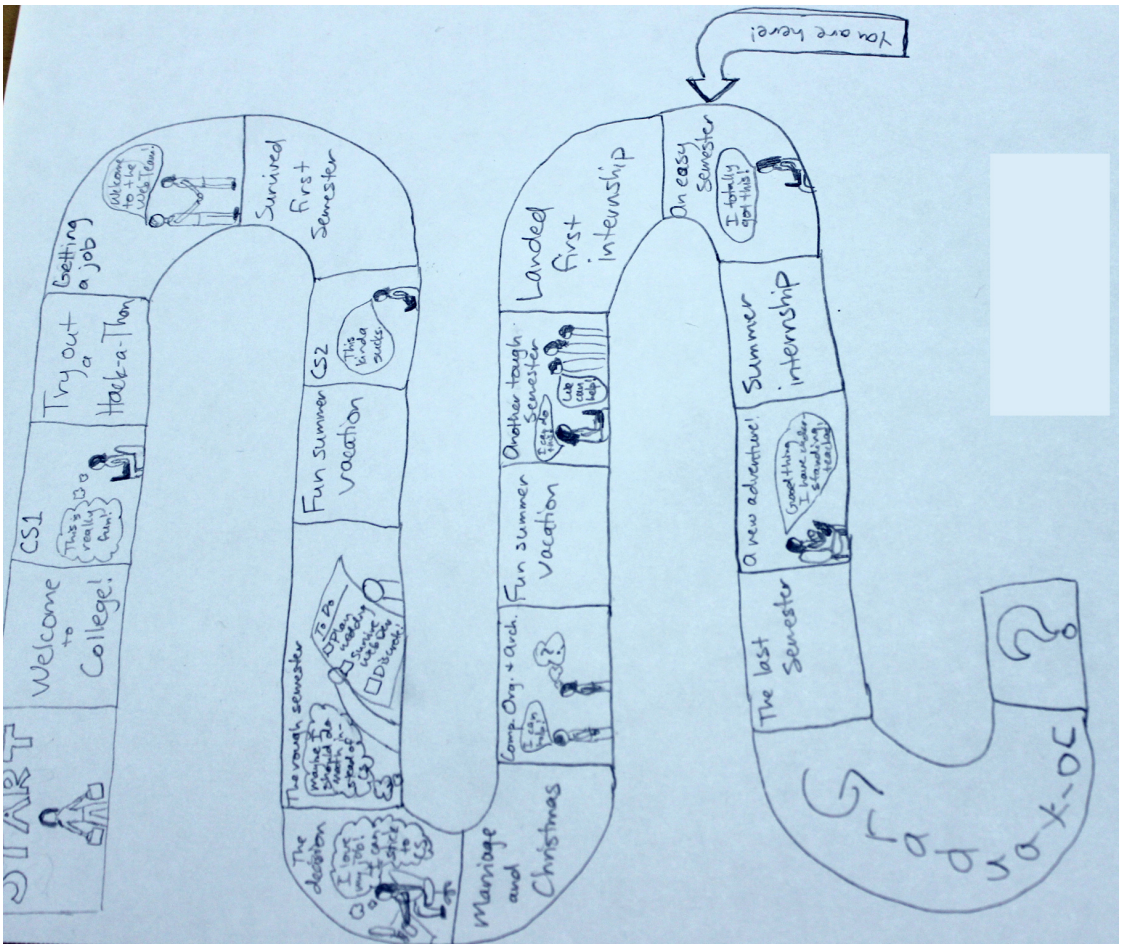
Case Study #10: Monica's Board Game Journey

Monica was a Junior when we met. She drew her journey map as a board game (see Figure I5), where different fields on the board represented different milestones that she reached along the way or different hurdles she had to overcome. The board game also included a note on where she was at the time of the interview, as well as what and how much was left ahead of her on her journey towards degree completion.

Monica started her college experience with no prior experience with CS but an interest in Electrical Engineering (EE). However, one of the first classes she took, a CS class, was so "fun" and interesting that she immediately switched her major to CS. Soon after, she decided to attend a Hack-a-thon, this "awesome" "computer-science party," where she participated in a learning activity with a person who ended up offering her a job mostly because he perceived her as someone who "can learn it." As all of this happened within her first semester, Monica had a feeling that it was all part of divine intervention.

Figure I5

Monica's Journey Map.



> I feel like this whole time, like I've been able to very much see – and, for me, I'm very religious so, for me, I feel like I've been able to see the hand of God kind of like nudging me, slowly, at the direction I'm supposed to go. (Monica, interview)

Being a religious person, Monica believed God was leading her way to the right career choice from the start, which was confirmed by each and every new opportunity that opened to her. Church, with all the activities Monica was involved in, remained crucial in providing her the balance she needed to balance hard coursework throughout her CS major experience. To maintain productivity, she also worked on having a balance of

structure and “down time,” which is how she referred to the time away from homework and other school-related activities.

With her second semester in college, classes got more challenging and less interesting. To persist and succeed, Monica started relying on other people, such as classmates and co-workers, who “helped [her] (…) when [she] got stuck” and “helped [her] get through it” all. Her sophomore year was particularly challenging as she was taking a combination of hard classes while also organizing her own wedding. During that period, a female friend, who took the same classes as she did, helped her the most. She did the necessary research on the assignments, visited the tutor lab and took the time to teach Monica what she needed to know and or do. This particularly challenging semester made Monica start wondering if she should switch to mathematics as she really enjoyed math and it seemed to be less challenging than CS. At that point, it was her job that kept her in CS, because it made her realize how much she “love[d] (…) everything that comes with computer science” from talking to the client to figuring “out how to put [their wishes] into code” to presenting about the finished project. At the same time, her job exposed her to a lot of good learning opportunities, helped her envision herself in the field and maintain self-confidence in her skills.

> My job has played a huge role in everything. I don't know if I could’ve made it without having that – just to have that something to remind me that I do have talents. I do know what I’m doing to some extent. I can apply my skills in work application like even with where I’m at, right now, I can still function successfully in a work environment. Even if I can’t learn everything perfectly, that I need to learn like I could still hold a job and do well. (Monica, interview)

In other words, despite difficulties in school, one of the major factors that influenced her persistence in the major was joy she felt doing her CS job. Her active participation at

work gave her a different perspective on her talents, expertise and skills. At the same time, it provided transparency on what it takes to keep a job and succeed in it.

Monica got married during Christmas of her sophomore year, which was followed by another "rough" semester. At that time, her husband emerged as one of the major pillars of emotional support, which he provided by believing in her, encouraging her to "take break[s]," sharing household responsibilities with her, embracing her CS friends, and similar. Monica also started relying on professors to the point where a few of them became her friends. Soon enough, she had a big network of friends inside the major, people that she could ask for help, work with and or organize study groups with. Like Jane, Monica started gaining legitimacy from helping others parallelly to drawing a lot of support for herself, as well.

> It helps me to have someone that I can talk to, and it helps me, both, to receive help and to give help because, when I can help someone else, it helps me feel like I am doing well in keeping up. When I have someone, I can ask for help, then, I don't feel as scared. When new things are happening, I'm like, ahh, like, I don't know how I'm gonna do this, but I'm sure that I can ask so-and-so, and we can figure it out together. (Monica, interview)

Having a lot of friends inside the major made the experience less stressful and scary for Monica. She had people she could turn to, talk to and ask for help. Being able to help others, on the other hand, allowed her to have an approximation (Brown et al., 1989; Lave & Wenger, 1991) of how good her own understanding of the subject matter was.

After her sophomore year, Monica went back to working full time over the summer. The fact that she was the only person familiar with the code on the project that she was in charge of was both rewarding and disheartening. On one hand, she was the one responsible for maintaining the project, but on the other hand, maintenance did not

take a lot of her time, which made her feel both bored and excluded from other projects.

During her third year, classes were still "rough," but Monica never stopped planning her CS future. She started applying for internships and got several interviews at a University Career Fair where company representatives were expressing admiration for both her experience and her GPA. She ended up getting two job offers. One of those two companies, however, told her she was "one of [their] three top choices," which both surprised her and "helped [her] feel validated," so she chose to accept their offer.

> It felt so good to be, like, you know, it's been hard, and it's been rough but, because I've worked so hard and because I've kept going, now I'm starting to see that it's having an effect. Like it's making people notice me, and it's making me more marketable as an employee, and that was just – it was really cool. (Monica, interview)

In other words, getting to a point where she not only got two job offers but a lot of professional praise, was really good for Monica's self-confidence. She realized that hard work paid off, and she felt good about herself professionally. The semester after this one was "easy" as she did not have to "pack a bunch of difficult classes" anymore and could count her work as one of her classes. As a result, she found herself in a much more comfortable place inside her major.

Appendix J

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Article Title	Factors that Influence Retention of Women in the Computer Science Major: A Systematic Literature Review	End Page	145
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		Expected presentation date	2020-05-02
Instructor name	Katarina Pantic		

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CURRICULUM VITAE

KATARINA PANTIC

1351 Edvalson Street
Department 1304
Ogden, UT 84408-1304

EDUCATION

Ph.D. in Instructional Technology and Learning Science (ITLS) May 2020
Utah State University, Logan, UT
Dissertation topic: Retention of women in Computer Science majors
Committee members: Dr. Jody Clarke-Midura (chair), Dr. Mimi Recker, Dr. Deborah Fields, Dr. Sherry Marx and Dr. Vicki Allan

M. S. in Communication, North Carolina State University, Raleigh, NC May 2012

B. A. in English Language and Literature, Uni. of Belgrade, Belgrade, Serbia Oct 2003

FUNDED PROPOSALS

Clarke-Midura, J. (PI, USU) & **Pantic, K.** (Student-Investigator). Retention of Women in CS Majors: Why Women Persist? Center for Women and Gender (CWG) grant, Utah State University, 07/01/2017-06/30/2018, $12,959.29 (amount matched by ITLS department)

APPOINTMENTS

Graduate Research Assistant/ Instructor Jan 2015-May 2020
College of Education, Dept. of ITLS, Utah State University Logan, UT

Webmaster Aug 2013-Aug 2015
College of Education, Utah State University Logan, UT

Communication Officer May 2012 – May 2013
Office of International Services (OIS), North Carolina State University Raleigh, NC

Graduate Teaching Assistant Aug 2010 – May 2012
College of Humanities and Social Sciences, Communication Department, North Carolina State University Raleigh NC

English as a Second Language (ESL) Teacher
Primary School Stefan Nemanja, Belgrade, Serbia Dec 2004 – Dec 2008
Language Studio Cosmopolitan, Belgrade, Serbia Jan 2002 – Dec 2004
Primary School Pavle Popovic, Vranic, Serbia Jan 2003 – Aug 2003

TEACHING EXPERIENCE

GRADUATE STUDENT INSTRUCTOR

Department of Instructional Technology and Learning Sciences 2017-present
Utah State University, Logan, UT

ITLS 3110 – Design Perspectives and Processes
(Format: online) (Semester: F2019)
Topics include: Human-centered/UX design, UX Research, product evaluation, design principles, usability testing, paper prototyping, storyboarding, sketching

ITLS 5500 – Technology Innovation and Integration into the Classroom
(Format: online) (Semester: F2019; SP2020)
Topics include: 21st c. education; ISTE standards; teachers as learners, designers and innovators; students are digital citizens, global collaborators, knowledge constructors and computational thinkers; podcast, multimedia handouts, screencasts, videos, teaching websites, lesson plans

ITLS 6540 – Learning Theory (co-instructor)
(Format: f2f and online) (Semester: F2019)
Topics include: behaviorism, cognitivism, constructivism, socio-cultural theory, constructionism, situated learning, motivation

ITLS 5205/6205 - Computer Applications for Instruction and Training
(Format: online) (Semester: SU 2017; SU 2018)
Topics include: applications for media authoring, editing, and delivery; usage of computer application in the development of instructional and training materials (such as Camtasia, Adobe Suite, Audacity, Qualtrics, Canvas etc.)

ITLS 5150/6150 - eLearning Trends and Issues
(Format: online) (Semester: SP 2017)
Topics include: best practices and future trends for online learning and teaching, such as moderation, curation of material, student role, community building and so on

GRADUATE TEACHING INSTRUCTOR

Communication Department 2011-2012
North Carolina State University, Raleigh, NC

COM 110 - Introduction to Public Speaking
(Format: f2f) (Semester: F 2011; SP 2012)
Topics include: Research skills, topic selection, speech organization, skills in speech delivery. Listening for analysis and evaluation of in-class speech presentation

GRADUATE TEACHING ASSISTANT

Communication Department 2010-2011
North Carolina State University, Raleigh, NC

COM 362 – Communication and Gender
(Format: f2f) (Semester: F 2010; SP 2011)

Topic include: Effects of gender on the interpersonal communication process. Construction of gendered identities via communication practices. Theories of gender and the role of gender in organizational, institutional, and media communication practices.

COM 230 – Introduction into Communication Theory
(Format: f2f) (Semester: S1 2011)
Topics include: Theories used in the study of human communication: perspectives and assumptions of major theories; utility and application; contexts, cultures, and media;

COM 447 – Communication and Globalization
(Format: online) (Semester: S2 2011)
Topics include: History and current trends in globalization of media, information, and telecommunications technologies, organizations, policies, and contents. Political cultural implications.

ENGLISH AS A SECOND LANGUAGE TEACHER

Stefan Nemanja Primary School 2004-2009
Belgrade, Serbia

English as a Second Language
(Format: face-to-face) (Grade: 1st – 8th)
Topics include: speaking, listening, writing, reading and grammar.

Language Studio Cosmopolitan Jan 2002 – Dec 2004
Belgrade, Serbia

English as a Second Language
Format: face-to-face) (Grade: 1st-4th & adult learners)
Topics include: speaking, listening, writing, reading and grammar.

Primary School Pavle Popovic Jan 2003 – Aug 2003
Vranic, Serbia

English as a Second Language
(Format: face-to-face) (Grade: 5thst-8th)
Topics include: speaking, listening, writing, reading and grammar.

RESEARCH EXPERIENCE

Graduate Research Assistant
Logan, UT

College of Education, Dept. of Instructional Technology and Learning Sciences
Understanding the Role of Gender in Engaging the Interest of Girls in Computer Science* [*Funded by NSF:* #1614849*] Aug 2016-Aug 2019

Performed activities: Mentored several Ph.D. students in grant- and research-related activities; Co-authored papers for journal and conference submission; Served as camp project manager; Collected and analyzed interview and focus group data; Co-

designed surveys, interview protocols, instruction and mentor training.

Retention of Women in CS Majors: Why Women Persist [Funded by USU CWG] Aug 2017-present

Performed activities: prepared USU CWG grant proposal; Designed & conducted a research study for the USU CWG grant; conducted systematic review of literature.

Children's Do-It-Yourself-Media: Insight and Connection [Funded by: Social Sciences and Humanities Research Council of Canada] Jan 2016-Dec 2016
Collaborator: University of Toronto

Performed activities: Used case study and statistical analysis on 120+ children's online DIY media sites to identify key opps and challenges associated with kids' production online.

Macro Data for Micro Learning: Developing FUN! for Automated Assessment of Computational Thinking in Scratch [Funded by NSF: #1319938] Jan 2015-Jan 2016

Performed activities: Co-authored papers for conference submissions; Conducted multimethod analysis of kids' projects and communication on Scratch.

Graduate Teaching Assistant **Raleigh, NC**

College of Humanities and Social Sciences, Department of Communication, NCSU

Collaborative Research: Developing a Culturally Compelling Social Network Approach to HIV/AIDS Prevention for African American College Students Jan 2012-June 2012

Performed activities: conducted focus group data collection; transcripts and data analysis.

Cross Regional Differences in HIV/AIDS Prevalence in Tanzania Aug 2011-May 2012

Performed activities: conducted focus group transcripts and data analysis.

SCHOLARLY PUBLICATIONS

PEER-REVIEWED JOURNAL ARTICLES

4. Clarke-Midura, J., Sun, C., **Pantic, K.**, Poole, F., & Allan, V. (2019). Using Informed Design in Informal Computer Science Programs to Increase Youths' Interest, Self-efficacy, and Perceptions of Parental Support. *ACM Transactions on Computing Education (TOCE), 19*(4), 1-12 (Article 37), doi: 10.1145/3319445

3. Pantic, K., & Clarke-Midura, J. (2019). Factors that Influence Retention of Women in the Computer Science Major: A Systematic Literature Review. *Journal of Women and Minorities in Science and Engineering, 25*(2), 119-145. doi:10.1615/JWomenMinorScienEng.2019024384

2. Pantic, K., Clarke-Midura, J., Poole, F., Roller, J., & Allan V. (2018). Drawing a

Computer Scientist: Stereotypical Representations or Lack of Awareness? *Computer Science Education Journal, 28,* 3. doi: 10.1080/08993408.2018.1533780

1. Clarke-Midura, J., Poole, F., **Pantic, K.**, & Allan, V. (2017). Playing mentor: A new strategy for recruiting young women into computer science. *Journal of Women and Minorities in Science and Engineering, 23*(3). doi:10.1615/JWomenMinorScienEng.2017019307

PEER-REVIEWED CONFERENCE PROCEEDINGS

5. Clarke-Midura, J., Poole, F., **Pantic, K.**, Sun, C., & Allan, V. (2018). How Mother and Father Support Affect Youths' Interest in Computer Science. In Proceedings of the 2018 ACM Conference on International Computing Education Research (ICER '18). ACM, Espoo, Finland, 215-222. doi: 10.1145/3230977.3231003

4. Clarke-Midura, J., Poole, F., **Pantic, K.,** Hamilton, M., Sun, C., & Allan, V. (2018, February). How Near Peer Mentoring Affects Middle School Mentees. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE '18)*. ACM, New York, NY, USA, 664-669. doi: https://doi.org/10.1145/3159450.3159525

   *Second best paper award

3. **Pantic, K**., Fields, D. A., & Quirke, L. (2016, June). Studying situated learning in a constructionist programming camp: A multimethod microgenetic analysis of one girl's learning pathway. In *Proceedings of the The 15th International Conference on Interaction Design and Children* (pp. 428-439). ACM. Manchester, UK. doi: 10.1145/2930674.2930725

2. Fields, D. A., Quirke, L., Horton, T., Velasquez, X., Amely, J., & **Pantic, K**. (2016). Working toward equity in a constructionist Scratch camp: Lessons learned in applying a studio design model. In A. Sipitakiat & N. Tutiyaphuengprasert (Eds.), *Proceedings of Constructionism* 2016 (pp. 291-298). Bangkok, Thailand. Available at http://e-school.kmutt.ac.th/constructionism2016/Constructionism%202016%20Proceedings.pdf

1. Fields, D. A**., Pantic, K**., & Kafai, Y. B. (2015, June). "I have a tutorial for this": The language of online peer support in the Scratch programming community. In *Proceedings of Interaction Design and Children*, (IDC '15). ACM, Boston, MA, USA, 229-238. doi:10.1145/2771839.2771863

IN PREPARATION

Clarke-Midura, J., Sun, C., & **Pantic, K.** (submitted to *Transactions on Computing Education*). Youth Making Apps: Recruitment Strategies to CS.

Clarke-Midura, J., & **Pantic, K.** (submitted to *Mind, Culture and Activity* journal). Benefits of a Three-Tier Near-Peer Mentoring Model in Computer Science.

Clarke-Midura, J., Sun, C., **Pantic, K.,** & Allan, V. (in preparation for *Computer Science*

Education). Near-Peer Mentoring as a Way to Foster Self-Efficacy and Interest in Informal Computer Science Environments.

*Clarke-Midura, J., & **Pantic, K.** (in preparation). Designing CS Experiences to Encourage Participation for Girls from Low Socioeconomic Backgrounds.*

*Clarke-Midura, J., & **Pantic, K**. (in preparation). Training CS Mentors: How Training, Modeling and Reflective Practice Support CS Mentors' Growth.*

*Clarke-Midura, J., Hamilton, M. M., **Pantic, K.,** Sun, V., Chauhan, A., & Allan, V. The Metamorphosis of Mentoring: From Trainee to Mentor*

REFEREED PRESENTATIONS

Pantic, K. Learning "Google Fu": Interactions and Practices that Enable Retention of Women in a CS Major. In *Storying the Intersectionality of Gender and Race in a White World* [Roundtable session]. AERA (San Francisco, CA), April 2020.

Clarke-Midura, J., Sun, C., & **Pantic, K.** The Influence of Gender Composition in Computer Science Camps on Girls' Self-Efficacy and Interest. In *Computer Science & Computational Thinking Self-Efficacy* [Roundtable session]. AERA (San Francisco, CA), April 2020.

Clarke-Midura, J., Sun, C., Hamilton, M. M., **Pantic, K.,** Poole, F., Allan, V. Near-Peer Mentoring as a Way to Foster Self-Efficacy in Informal Computer Science Environments. In *Peer, Adult, and Parent Facilitated Learning in Informal and Museum Settings* [Roundtable Session]. AERA (Toronto, Canada), April 2019.

Pantic, K. & Clarke-Midura, J. Designing CS Experiences to Encourage Participation for Girls from Low Socioeconomic Backgrounds, In *The Persistence of Women and Girls in Educational Settings* [Roundtable session]. AERA (Toronto, Canada), April 2019.

Clarke-Midura, J., **Pantic, K.,** Poole, F., Allan, V., Dorward, J., & Hamilton, M. Making Apps: A Near Peer Mentoring Program for Girls. In *K. A. Searle & B. K. Litts Making at the Margins: Engaging Underserved Communities in Maker Technologies, Activities, and Spaces* [Structured Poster Session]. AERA (New York, NY), April 2018.

Pantic, K. & Clarke-Midura, J. Retention of Women in CS Majors [Poster Session]. RGS Student Research Symposium (Logan, UT), April 2018.

Pantic, K., Hamilton, M., Wood, L., & Balderas, A. Integrating App Inventor into your Programming Efforts. 4-H Computer Science Pathway Training, July 2017, Lehi, UT.

Pantic, K., Brasiel, S., Poole, F., Ames, C., Yuan, M., & Martin, T. Changed in student perceptions following mathematics education technology implementation. AERA (Washington DC, VA), April 2016.

Kiwanuka-Tondo, J., Merritt, S., Lavelle, M., **Pantic, K.,** & De Moya, M. Cross regional differences in HIV/AIDS prevalence in Tanzania: How socioeconomic and cultural contexts affect the perceived individual and group efficacy. Presented at Annual

Convention of AEJMC, Washington DC, August 2013.

Honeycutt, B., Hester, K., & **Pantic, K**. Intercultural Communication in the US Classroom (CoAT Workshop), NCSU, March 2013

Pantic, K., Educational Systems: Tacit Knowledge and Effective Cross-Cultural Communication (Information Session), International Education Week, NCSU, November 2012 (video)

Pantic, K. Wives of International Students: Coping Mechanisms Restrictive Visa Holders Use to Overcome Culture Shock, SSCA, San Antonio, TX, April 2012

Tallapragada, M., Dannels, D. & Pantic, K. (2011). The Foreign Voice: Using Research and Narratives of International Teaching Assistants to Design Training and Development [panel discussion], New Orleans, LA, November 2011

Pantic, K. Entering American Culture and Experiencing Culture Shock, OIS International Student Orientation, August 2011

Gossett, K., Lavelle, M., Liu, T., & **Pantic, K.** Student Sociocultural Adaptation: A Study of Self-Esteem, Intercultural Communication Apprehension, and Geographic Origin. 1st Annual International Engagement Exposition, Raleigh, NC, April 2011 (poster presentation)

Gossett, K., Lavelle, M., Liu, T., & **Pantic, K.** Student Sociocultural Adaptation: A Study of Self-Esteem, Intercultural Communication Apprehension, and Geographic Origin. 1st Annual International Engagement Exposition, Raleigh, NC, April 2011 (poster presentation) 4th NCSU Graduate Symposium, Raleigh, NC, March 2012 (poster presentation)

AWARDS

Graduate Student Instructor of the Year 2020
Instructional Technology & Learning Sciences, Utah State University

Doctoral Student Researcher of the Year 2019
Instructional Technology & Learning Sciences, Utah State University

Byron R. & Shirley Burnham Research and Development Award, $1000 2018
College of Education and Human Services, Utah State University

Legacy of Utah State Award 2018
Instructional Technology & Learning Sciences, Utah State University

Second Best Paper Award: **CS Education tract** 2018
49th ACM Technical Symposium on Computer Science Education (SIGCSE), Baltimore, MD

Graduate Student Instructor of the Year 2017
Instructional Technology & Learning Sciences, Utah State University

Competitive student paper 2012
Southern States Communication Association (SSCA) conference, San Antonio, TX

SERVICE

Peer-reviewed Journals

Reviewer for Journal of Women and Minorities in Science and Engineering (JWMSE) 2018-now

Reviewer for International Journal of Multicultural Education 2018

Conference Reviewing

Reviewer for Interaction, Design and Children (IDC) 2020

Reviewer for ACM Symposium on Computer Science Education (SIGCSE) 2017-now

Reviewer for FabLearn Conference 2015-2016

Utah State University

Judge, Utah Conference on Undergraduate Research (UCUR) 2020

Department of Instructional Technology and Learning Sciences

Faculty Search Committee Member 2018-2019

Vice President, Instructional Technology Student Association (ITSA) 2016-2017

North Carolina State University, Department of Communication

Secretary, Communication Graduate Student Association (CGSA) 2011-2012

Small Group Leader, Office of International Services 2009-2012

SKILLS

Data collection and data analysis: **MaxQDA, Qualtrics, SPSS, Excel**
Programming: **Dreamweaver, HTML, CSS, App Inventor, Scratch**
Learning Management Systems: **Canvas, Moodle**
Content Management Systems: **Wordpress, Omniupdate, Weebly, Google Sites**
Web conferencing: **Zoom, Elluminate Live!, Adobe Connect, WebEx**
Computer Applications for Instruction and Training: **Photoshop, InDesign, Camtasia, Jing, Adobe Premiere, iMovie, Publisher, wikis, Storyboard, Audacity, podcasts, Lucidpress, Screencast-o-matic**
Other: **APA, Spanish, Serbian/Croatian/Bosnian**

OTHER PROFESSIONAL DEVELOPMENT

Received teaching training: *Certificate of Accomplishment in Teaching, NCSU, 2012*
2013 NCAIE Spring State Conference at NC A&T, Greensboro, NC, 2013
F-1 Beginner, *NCAIE Fall Immigration Workshop*, Winston Salem, NC, 2012
Small Group Leader and volunteer, OIS, NCSU