Cascaded Mentoring for Gender Inclusion in Computer Science

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Over a ten-year span, from 2004 to 2014, the proportion of undergraduate degrees awarded to women in computer science (CS) declined from 25.1% to 18.1% (NSF and NCSES 2017). This continues a trend downward from a peak of 37% in 1985 (NCWIT 2018). These decreases have been attributed to a myriad of factors, including access to and encouragement with computers in the home, early exposure to computer science in schools, stereotypes about computer science, and a lack of role models who are women (Sax et al. 2017). Many attempts have been made to address this downward trend through small-scale interventions in curriculum and instruction. As an example, first-level undergraduate CS courses have made changes to the domain of computing projects to become more aligned with the interests and motivators of the women in the course (Margolis and Fisher 2002; Rosser 1990). Another small-scale intervention has been to address the classroom environment in order to remove signifiers that tie computing to other items of interest to young men, such as science fiction or video games (Cheryan, Plaut, Davies, and Steele 2009). Despite the good intentions of these approaches, it is becoming clear that they are not enough to reverse the decline in interest by women, and that an institutional change is necessary. For example, intervention programs in STEM, such as Purdue University's NSF-funded Louis Stokes Alliance for Minority Participation (LSAMP) and the Alliance for Graduate Education & Professoriate (AGEP) programs are initiatives that provide a range of mentoring experiences for underrepresented undergraduate students. Additional programs including Purdue's Pair Mentoring, Mentees and Mentors with Purdue's Women in Engineering, and Mentoring @ Purdue are strategically designed to support women and minority graduate students in different colleges. In this article, we make an argument based on two specific related interventions. First, we will advocate for the implementation of a mentoring model across undergraduate, graduate, and early career levels with the goal of building stronger connections between women in computing. Our second recommendation will be to celebrate faculty and university leaders – the "hidden heroes" of computing – thus enhancing the profile of these individuals within the university community and creating new role models for students to emulate. In combination, we believe that these two initiatives can positively impact perceptions of computer science across the university, and in turn, will lead to increases in participation rates for women in computing.

Computer Science Identity, Self-efficacy, and Belongingness

Before exploring our proposed interventions, it is important to understand the underlying factors that these interventions are aimed at affecting – computer science identity, sense of belongingness, and self-efficacy. Each of these factors, as we will discuss in detail, plays a role

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in whether women in computer science will stay engaged with the field. In a meta-analysis of studies focused on participation of women across STEM disciplines, Cheryan et al. (2017) identified a number of factors that contributed to a lack of interest in computer science. This included negative stereotypes about the participants in computer science, negative stereotypes about women's abilities within those fields, and a lack of relatable, female role models within computing. Negative stereotypes impact a student's identity within the field, and a lack of role models can impact their sense of belongingness. Cheryan et al. (2017) also noted that the outcomes related to self-efficacy were mixed across studies. Within computer science, however; there is evidence that self-efficacy for women in computing is much lower than it is for men (Beyer 2014). There are a number of interventions that could conceivably address identity, belongingness and self-efficacy, but we will illuminate why the combination of mentorship and localized role models were specifically selected to address these factors.

Identity is defined as the way in which an individual sees a domain, like computing, as being related to who they are (Baumeister 1997). A student can have multiple identities, for which their scientific identity is but one part. As a student engages more deeply with her scientific pursuits, her identity in that area is likely to increase (Brickhouse, Lowery and Schultz 2000). Looking specifically at gender differences, a study of introductory-level computer science undergraduates found that women showed significantly lower self-efficacy and lower perceptions of their roles within computer science (Dempsey et al. 2015). The authors further found that women's interest in pursuing computing careers was strongly linked to their belief in their ability to perform in computing classes and their self-identification as computer scientists. Considering these effects on identity, it follows that any intervention in computer science that aims to improve the participation rate of women should focus on building student identity in computing.

Closely related to the construct of identity is the concept of belongingness. A person's sense of belongingness is his/her feeling of inclusion in dominant groups of the culture within which he/she exist (Baumeister and Leary 1995). A lack of belongingness in the dominant culture in academic fields has serious repercussions. Students who do not feel as if they belong are significantly less likely to ask questions in class or attend faculty office hours. On the other hand, students with a higher sense of belonging are more likely to persist through the major. A study of multiple retention factors in CS found that a student's personal values and sense of belonging were more critical to student retention than their perceptions regarding the usefulness of the degree to future success (Giannakos et al. 2016). Belongingness in CS is strongly related to the environment itself, and a successful intervention to address the inclusive atmosphere for women in CS must be substantial enough to change how the student perceives this atmosphere.

The final factor that we wish to address is self-efficacy. A person's self-efficacy beliefs are the extent to which they feel confident that they can accomplish a given task (Bandura 1977). In the context of academic pursuits, self-efficacy is highly correlated to student success in a number of fields, including in computer science (Honicke and Broadbent 2015; Lishinski et al. 2016). It is known that self-efficacy and academic performance have a reciprocal relationship, which suggests that women in CS need to experience academic success to build on their academic self-efficacy. Addressing the environment in computer science such that women are able to build on successive positive experiences will in turn positively affect their self-efficacy. While it is only one aspect of maintaining CS identity and a sense of belongingness, it is thought that self-efficacy within a domain helps to enhance both of these factors (Trujillo and Tanner 2014). We next introduce mentorship and role modeling as a means of addressing computer science identity, sense of belongingness, and self-efficacy.

Mentoring for Recruitment and Retention of Women in CS

One way that identity and sense of belongingness can be developed is through perceived similarity with those already identifying within the domain. The impact of seeing similar others helps build identity in a number of ways. Women that have yet to form a strong computer science identity need to see other women who have been successful in the field in order to inoculate themselves from existing stereotypes in the field (Dasgupta 2011). A number of stereotypes in computing suggest that masculine perspectives and interests are important to participation and success in the field (Cheryan et al. 2009). By establishing the existence of successful women and connecting them to other women in computing, the magnitude of the effect of the stereotypes within computing can be reduced. Finding similar others also provides students with models of successful behaviors within computing. Those with whom the student perceives similarity act as role models in identity development, and through emulating these role models, a student can show increased self-efficacy and self-confidence (Finzel, Deininger, and Schmid 2018). The challenge is in identifying individuals to serve as role models for women in CS.

An important pathway for connecting developing computer scientists with appropriate role models is through mentoring relationships. According to Chesler and Chesler (2002), mentoring is a developmental relationship whereby an experienced person provides both technical and social support to a less experienced person. Mentoring provides a promising individual with an established figure in the field of interest with whom he/she can see similar or desirable traits, be counseled through unfamiliar circumstances, gain acceptance with the field, and find confirmation about established beliefs (Kram 1983; Rosser 2012). For an undergraduate student who is entering an academic field, this can be invaluable in helping the student to navigate the unknown culture within that field. This is particularly true in computer science, where undergraduate students enter the field with a wide range of experience levels and understandings of what computer science entails. In addition to the general variation in first-year computer science student experience, the dominant culture can also provide challenges for undergraduate students that do not feel as if they belong. Women in computer science programs have pointed to the computing culture as having reduced their sense of belonging and, in many cases, this has led to their departure from the major (Lewis, Anderson, and Yasuhara 2016). The role of a woman mentor goes beyond guidance in computer science. This person can serve as a representative in computing who has had success in spite of the dominant culture. As noted before, this person can then inoculate the mentee against computing stereotypes as she explores her interest in computer science.

Thus far, we have considered the benefits of mentorship to the mentee, but there is ample evidence that the individual acting as the mentor experiences positive benefits as well. One significant benefit comes from the mentor’s increased satisfaction in both their professional outcomes as a result of their mentee relationship, and with the organization that supports their engagement in mentoring (Ghosh and Reio 2013). Considering that women faculty and graduate students in computing are also underrepresented, the mentor roles can serve to reinforce their desires to remain within the computer science department. Another benefit for mentors in computing is the opportunity to express their passion for the field through teaching mentees. By sharing their knowledge and demonstrating their competence, the mentor can improve their self-efficacy within computing. These benefits for both mentors and mentees require a commitment to engaging in best practices for mentoring, which we explore in the next section

Mentoring Best Practices

There are several different models of mentoring from which to discuss best practices. These range from traditional (two-person, mentor-protégé relationship) to alternative (mentoring community of diverse helpers or distributive mentoring) approaches (Chesler and Chesler 2002). More traditional models tend to favor a unilateral relationship based on varying levels of experience, gender, and interests (Packard 1993; Seymour 1995). Alternative approaches focus more on building broad, diverse, and collective networks of mentors that are often supported if not endorsed by an organization (Seymour and Hewitt, Tierney and Bensimon 1996). Underpinning each of these models is the emphasis on cultivating support, guidance, and trust between the mentor(s) and mentee. While all these approaches have merit, we will focus our discussion of best practices on those models that are recommended specifically for working with women in STEM fields. Furthermore, we highlight approaches that take the current concerns regarding limited existing women faculty and graduate students into account when making these recommendations.

Looking specifically at best practices for mentoring women in STEM fields, we consider the following factors: proper mentor training, collaborative learning experiences, peer mentoring circles, and cross-gender mentoring. A successful mentoring program is dependent highly on the training of mentors to engage in best practices from successful mentoring programs (Pfund et al 2006). This includes issues of communicating effectively, understanding students from diverse backgrounds, and reviewing various mentoring styles. In computer science, one successful mentor training model that addresses these items can be found in Mount Holkyoke's MaGe program. Working collaboratively between peers and in the mentor-mentee relationship can aid in both the freedom to communicate concerns about expectations and interactions within the shared domain, and in improving career competencies (Gorman et al. 2010). This was deemed particularly important given that perceptions were that performance expectations for women were higher than they were for men in academic environments. Thomas, Bystydzienski and Desai (2014) encouraged the development of peer mentoring circles as a specific solution for women in STEM fields. These circles would provide a collective group that could address the shared needs of the participants while also unearthing trends that could be seen across individual experiences. Chesler and Chesler (2002) argue for the use of cross-gender mentoring relationships in STEM fields due to the less frequent presence of women in STEM departments.

One specific reason for this is due to the power-differential that exists in these departments for women faculty members. In these situations, the authors warn against falling into the pitfalls of typical male-centered mentoring programs by making the following recommendations. First, they suggest that the purpose of the mentoring be clarified so that informational and technical aspects do not subsume psychosocial aspects. Second, they emphasize that the role of the mentor should not be strictly to challenge the mentee, and that instead the mentor should structure their efforts to help form collaborative efforts to accomplish in-domain tasks.

Utilizing these best practices provides a solid base for mentoring women at multiple academic levels within a computer science department. Beyond this, however; we wish to present an approach that can serve as a connective tissue between participants. This approach is one that will allow participants to build their self-efficacy within computing while also providing a long-term connection to mentoring practice at multiple levels of participation. We will explore this mentoring model in the next section.

Cascading Mentorship at the University Level

With mentorship playing an important role in the development of identity, sense of belongingness, and self-efficacy for women in computer science, we now consider our first recommendation for institutional change. To maximize the recruitment and retention of women across K-12 education, undergraduate and graduate studies, and at the faculty level, we emphasize the importance of a multi-level cascading model of mentorship. In this model, undergraduate students who have been supported as mentees transition to become mentors for the group of students that follow them. Cascaded mentorship was implemented at the university level in a study of a service learning course focused on engaging undergraduate students in the transformation from learners to teachers (Kafai et al 2013). This course was designed as an alternative representation of computing, working against stereotypes of antisocial students engaging in isolated, non-creative work. The undergraduate students were trained as teachers and mentors, and then were sent to local high schools to implement a series of introductory computer science lessons. At the end of two years, both mentors and mentees reported higher interest and higher self-efficacy in computer science. The researchers emphasized the shift in roles as the major factor in the positive outcomes of the study. The undergraduate mentors relied on their recent experience as new computer science learners to inform their work addressing the needs of the high school mentees.

Some computing departments may struggle to find significant numbers of graduate students and faculty members to build a strong mentorship model. In 2017, women made up 15.1% of faculty members, 18.3% of the PhDs awarded, 26.1% of the Master's degrees awarded, and 19.0% of the Bachelor's degrees awarded in computer science in the United States (Zweben and Bizot 2018). In addition to the challenge presented to successful mentorship programs from low numbers of potential participants, there are also a number of costs associated with taking on the role of mentoring students. Generally speaking, the most significant cost to mentors regardless of gender is the significant amount of time that must be dedicated to mentoring practice, at the expense of teaching and research (Morales, Grineski, and Collins 2017). For women in STEM departments, additional costs can include the magnification of successes or failures through mentoring due to the imbalanced power structure in a department, the reduction of time for focusing on their own careers, and an overload of mentees due to their lack of peers (Ragins and Scandura 1994). These concerns are challenging to address but based on the aforementioned peer mentoring circle recommendation (Thomas et al. 2014), one possible solution would be to encourage faculty and graduate students in CS to engage in group mentoring. In addition, these groups could invite women from similar departments to participate in these mentoring circles, particularly in areas where this connection may benefit these outside faculty members. The increased load on women in computing should also be recognized from within the institution, perhaps by providing increased stipends for taking on mentoring positions, or through travel support for women to participate in national efforts to engage women in computing.

An idealized version of cascading mentorship may feature faculty relationships with undergraduate and graduate students, relationships between graduate and undergraduate students, and an extension into the K-12 schools. At each level, there are opportunities for participants to be both mentors and mentees. The benefit of connecting women across levels and providing mentoring support for graduate students, undergraduate students, and pre-college students is that it further bolsters the pipeline of students and begins to systemically change the culture of computing at the university level. The major implementation challenge originates from the diminishing number of women in computing at higher levels in the department. There are fewer upper-level undergraduate women than lower-level undergraduate women, fewer graduate women than upper-level undergraduate women, and fewer women faculty than graduate women. The challenge at the institutional level becomes the ability to find role models at the top level of the chain. In the next section, we look at ways in which the cascading mentorship model can be enhanced through the promotion of the "hidden heroes" of computer science departments.

Faculty "Hidden Heroes"

Establishing a mentoring model with upperclassmen aiding underclassmen, or undergraduates aiding K-12 students is only one component of our proposed program for addressing the underrepresentation of women in computing. Specific role models have proven to be essential for the recruitment and retention of women in STEM fields (Rosser 2012). To address the lack of role models for women in computing, we contend that the next step must involve recognizing the existing university faculty as the "hidden heroes" of computer science. Why use the expression, "hidden heroes" to describe the women of the computer science faculty? To answer this, we will first look at the ways in which the roles of women in science generally, and computer science specifically, have been historically marginalized.

The history of women in science whose contributions have been overlooked or undervalued is lengthy. Well-known stories, such as those of Rosalind Franklin and Barbara McClintock, serve as examples of insightful women whose work was not recognized in their time. In Franklin's case, her work determining the molecular structure of DNA was subsumed by James Watson and Francis Crick. For McClintock, her many biological discoveries regarding chromosomal crossover in maize and transposition effects were not recognized until men found similar outcomes years afterwards. Many other women have toiled in anonymity, either due to explicit or implicit androcentrism in their fields. This list includes notables, such as Jocelyn Bell Burnell, whose discovery of pulsars in 1967 resulted in her supervisor's Nobel Prize award in 1974 (Burnell would eventually be recognized by Nobel with the 2018 Breakthrough Prize), and Chien-Shiung Wu, who disproved the law of parity among atoms but was also excluded from the Nobel Prize award in 1957 that her collaborators received. Despite a modern educational culture that has worked to celebrate these women, it is likely that there are many others who have not received their due. This includes women working in academic settings across the world who are still facing challenges similar to those that obscured the work of the great women discussed above.

In computer science, the lack of representation of women at the more visible levels presents a major concern, particularly considering the need to present younger women with models for success within the field. The computer science community celebrates the work of Admiral Grace Hopper, whose work on computer compilers has allowed for a wider range of people to program computers. Other celebrated computer scientists from history include Ada Lovelace, who conceptualized general purpose computing for Charles Babbage's Analytical Engine, and women like Katharine Johnson and Dorothy Vaughan, who worked for NASA to calculate orbital paths for the Apollo program. These contributions are vital, but in isolation are not enough to dispel the notion that computing is only for men. How should computer science departments work to alter these perceptions? One strategy would be the use of near-peer mentoring models. This strategy, in which mentors are similar in age, background, and personality to their mentees, has been successful in reducing the effect of limited visibility for potential role models (Tenenbaum et al. 2014). This aspect of the cascading mentorship model however does not provide role models who have accomplished success at the highest level of computing. In order to enhance the university computer science community, a CS department needs to leverage their most vital existing resource. This means celebrating the women that are already on campus, working as graduate students and faculty members. In other words, commending women in computer science who have overcome inequalities in the classroom and/or workforce, persisted in the academy, and accomplished academic milestones. These women, regardless of years tenured, are highly accomplished within the field, and have had to persevere through the gender-imbalanced world of graduate computer science to reach their current successful positions. These women include early to late career faculty as well as graduate students in computer science. They possess two essential qualities for providing role models for aspiring computer scientists: a recognizable high-level success in computing, and a localized, approachable presence in the university community.

Women in the computer science faculty need to be celebrated as the "hidden heroes" of computing. By sharing these women's success stories, it provides others in the academic community with a model to emulate at the intersection of computer science and feminism. In addition, the celebration of women faculty validates the unique challenges faced by women in computer science and allows the "hero" to speak of the persistence and determination that allowed her to achieve at such a high level. As students move through the computer science program, they will undoubtedly face their own challenges. With knowledge of a "hero" who had provided direct or indirect support to the student, these challenges may seem less daunting. The "hero" becomes the role model that so many women in computing need to help develop their computing identity. For a university computer science department, looking inward for these hero role models establishes the importance of these women to their computing culture.

Conclusion

Existing practices to address the underrepresentation of women in computer science have been limited in their impact. While small-scale mentorship programs have shown signs of success among a number of other limited interventions, we argue that true change will be the product of a committed effort to engage mentors and mentees across multiple levels of the computer science department. Helping with the impact of this process will be the intentional promotion of the "hidden heroes" among computer science faculty. These approaches are rooted in efforts to address the need to inoculate women in computing from existing stereotypes, and also the benefits of improved computer science identity, an empowered sense of belongingness and self-efficacy. As if this was not enough of an argument for institutional change, there is an added benefit to committing to a panoptic transformation. Celebrating women in computer science and implementing a cascading multi-level mentoring program demonstrates a commitment to the women currently at the university, and in turn, creates an actively inclusive environment that will attract more women to the department. Over time, the representation of women in the computer science department will increase, and this can help to augment the culture in a way that it no longer is defined strictly from a masculine perspective. This strategic commitment to fundamental change is not trivial, and the benefit to all participants in the university community is significant enough to merit the investment.

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