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Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory

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Keywords

Computer science, theory, identity, intersectionality

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The Need for Enhanced, Intersectional Computing Identity Theory

The computing industry is facing several key demands that put unique pressures on this field to attract and retain more and diverse students to computing. This pressure is prevalent around the globe but is particularly pressing in countries like the United States, where more computer science graduates are needed to fill jobs in the growing computing and information technology sector (Bureau of Labor Statistics [BLS], 2015). Current estimates suggest that there are 263,586 unfilled industrial technology jobs in the United States, with unemployment in the tech industry hovering at only about 2.8% (Florentine, 2017). When companies cannot fill jobs due to a lack of skilled workers, the cost to the economy is significant. Research from the job listing site Glassdoor.com estimates that in the United States the cost of current unfilled jobs in the tech sector is over $20 billion (Chamberlain, 2017).

Not only is there is demand for more college graduates with computing degrees in general, but a great deal of emphasis has been placed on recruiting and retaining women and underrepresented minority (URM) students into computing fields in particular (e.g., code.org, 2013; The White House, 2016). The United States' National Science Foundation (NSF, 2014) designates African American/Black, Latino/a, and Native American students as URM students. In 2016, women and URM students each earned about 19% of all computing degrees awarded in the United States (National Center for Education Statistics (NCES), 2017). Women make up the majority of bachelor's degree recipients (NCES), 2017), and the proportion of college students who are URMs is increasing (NCES, 2015). If colleges and universities fail to attract and retain more women and URMs to computing majors, it will be difficult to meet the demand for individuals with tech backgrounds, given the changing demographics of the US collegiate population. In addition, the US will find it difficult to remain competitive within the global computing industry, for a diverse workforce of computer scientists produces a spectrum of innovative solutions which have the ability to consider race, ethnicity, gender, and class, among other identities. Without new, diverse computer scientists, knowledge will stagnate and innovation will be thwarted.

While the economic justifications discussed above are important to garnering support from industry for diversifying the computing field, there is a larger societal imperative to bring more women and URMs to computer science. On a personal level, individuals with computing backgrounds will have economically advantageous career opportunities. Computing careers, which are growing at twice the rate of the national average, tend to pay higher wages, provide better benefits, and be more resilient to economic shifts than other industries (U.S. Equal Opportunity Commission [EEOC], 2016). The Bureau of Labor Statistics (2018) suggests that computer and information technology careers have higher median annual wages ($82,860) than all other occupations ($37,040). Women and URMs should have equal access to such opportunities. Indeed, recruiting and retaining more women to computing may address issues such as closing gender pay gaps (Lim, 2016; St. Rose, 2010).

Today's society is undergoing a clear digital transformation and individuals of certain marginalized groups may be limited in their ability to take part in that movement. The digital divide can be seen in the rapidly uneven distribution of computing careers across the nation's workforce, by various identities, such as race, gender, and class (Muro, Liu, Whiton, Kulkarni, 2017). To address underrepresentation and ensure that digitalization happens as a democratic process, it is imperative that this sector not only has a diverse group of people developing the technology but we must also allow all groups to have access and participation in the digitalization process. On a societal level, computer scientists play a large role in creating the technology that drives society; in order for technology to serve our diverse society, we need diverse people making that technology. Since a computing degree is seen as a valuable commodity within today's job market, it is imperative that colleges and universities seek to create equitable outcomes for students who, across time, have been systematically marginalized from computing disciplines and careers.

As colleges and universities seek to recruit and retain more students in general to computing, as well as to attract more women and URM students to computing majors, they must maintain a difficult balance between the two imperatives. During past periods of increasing interest in computing, the gender gap, or difference in the proportion of men and women majoring in computing, has grown. This has led many in the tech industry and in academia to worry that even as current enrollments in computing majors grow, women's interest may not keep pace with men's, thus making the field become more homogenous. For example, Sax and colleagues (2017) found that from 1990 to 2000, the proportion of college men planning to major in computer science grew from 3.3% to 9.3%. During that same time period, however, the proportion of women planning to major in computer science only grew from 1.5% to 1.9%. And, despite gains in enrollment and persistence, racial and ethnic minority students continue to earn fewer bachelors and doctoral computing degrees than White and Asian students (National Science Foundation, 2017). Hence, as higher education works to meet the demand for more computing graduates, it will also have to redouble efforts to increase the major's diversity in terms of gender, race, and ethnicity.

As students make the decision to pursue and persist in a computing major an important component of that process is the extent to which they identify as a computing person. That is, students must come to feel a sense of fit with the field (Lewis, Yasuhara & Anderson, 2011, Lewis, Anderson & Yasuhara, 2016) and see themselves as computer scientists. We argue that the development of a computing identity is a negotiated process that is shaped by structural forces. Structural barriers are those that exist beyond an individual's control. As Margolis and Fisher defined it with respect to women in computing, structural inequalities amount to "weighty influences that steal women's interest in CS away from them" (2003, p. 6). Computing departments that have sought to address structural barriers to students' self-recognition as computer scientists have been successful in increasing the representation of women in undergraduate computing (e.g., Margolis & Fisher, 2003; Weisul, 2017). As will be discussed in more detail in later sections, there are a number of aspects of computing environments that may present obstacles for some students, particularly those from underrepresented groups, to envision themselves as computer scientists.

Socialization is chief among the structural forces that may inhibit students' computing identity development. Socialization is a process in which an individual learns and internalizes the social norms, ideologies, and values within a given context (Clausen, 1968; Macionis, 2013). Societal expectations and attitudes may influence how an individual experiences the computing environment, particularly for women and URM students. In fact, research has shown that an important factor in students' decision to pursue and persist in a computing major is the extent to which they feel a sense of fit with the field (Lewis, Yasuhara & Anderson, 2011, Lewis, Anderson & Yasuhara, 2016). As will be discussed in more detail in later sections, there are a number of aspects of computing environments that may present obstacles for some students, particularly those from underrepresented groups, to envision themselves as computer scientists. When college students were asked why women are underrepresented in computing, many of them felt that various aspects of gender socialization, including stereotypes and socialized beliefs about who can succeed in computing, was the main culprit (Varma, 2010). Therefore, when women encounter computing environments that reinforce stereotypes about computing as a masculine discipline, it is not surprising that they may question their decision to choose or continue in a computing field (Cheryan, Plaut, Davis & Steele, 2009; Lewis et al., 2016). Hence, a central goal of computing education scholarship should be to increase understanding of the unique aspects of *computing* environments to illuminate obstacles that might inhibit computer science students in moving towards a more fully developed *computing identity*. Further, understanding how college students develop a computing identity and why some students fail to see themselves as computer scientists may be key to designing effective strategies to recruit more students, particularly more women and URM students, to the computing major and retain them in the field. Finally, creating a greater theoretical understanding of the computing identity development process will inform the way in which educational stakeholders consider computer science practices and policies and create more equitable learning environments.

Overall, this paper advocates borrowing from established sociocultural understandings of identity development to enhance the way that we understand computing identity development by utilizing an intersectional approach in order to create more equitable computing outcomes. We develop these concepts by integrating insights from identity research, intersectionality, and by setting it into the context of computer science education research. Based on that, we advocate applying intersectional computing identity theory to practice in order to expand equity. We also offer suggestions on what should be investigated in the future and how that might contribute to a better understanding of classrooms, advising and mentoring, applied learning and problem-solving experiences, and department-level curricula and university level initiatives.

Using Computing Identity Development as an Analytic Lens

The concept of identity has emerged as an important research tool, particularly for understanding issues related to diversity in science education research (Pozzer & Jackson, 2015). Examining computing identity can enhance the pursuit for a more equitable education. Understanding identity development for computer scientists may be particularly important, given the nationwide push to recruit more students into computing and retain them in technical positions in the computing sector as well as the commitment to closing racial, ethnic, and gender gaps in access, degree persistence, and career opportunities facing this field.

Whereas a psychological approach to identity would preference the individual or small group, we advocate a sociological approach that would look beyond the individual to examine identity experiences in terms of society. Individual identity experiences have a lasting influence on the way that marginalized students perceive themselves and navigate their own computing experiences. However, if we think of identity experiences in terms of a sociological approach, it allows us to address larger, more systemic issues of underrepresentation experienced by women and URMs in computing. A sociological approach also allows scholars and practitioners to look across individual and group experiences in order to address structural issues and understand computing in terms of who is being privileged or marginalized in the current system. Groups with privileged identities are granted special rights or advantages in society based solely on the nature of their identities. Privileged identity groups establish norms for accepted behaviors, have access to greater opportunities for success, and possess power over marginalized groups. Within computing, a sociological approach to identity connects the concepts of privilege and marginalization to the creation of equitable educational outcomes.

Though the concept of identity has gained prevalence, scholars employ varied conceptualizations of the term, such that identity may be individually possessed or constructed and negotiated through interactions (Pozzer & Jackson, 2015). As Pozzer & Jackson (2015) describe, when thought of as something that can be possessed, computing identity, like other forms of identity, is more stable and constant than that which is constructed and negotiated. Possession of identity centers upon the idea that each individual has a relatively stable core identity which, to a certain degree, may be shaped by one's societal roles, can change over time and across contexts, and become more or less salient depending on those contexts.

However, this perspective neglects to address the dynamic nature of identity development and the crucial role that peers, faculty, staff, and many others take in this process. When thinking of identity as constructed and negotiated through interactions, computing identity development can be defined as how students understand, negotiate, and are recognized for their role within the computing field (Burke & Stets, 2009; Downey & Lucena, 2003; Tonso, 2006; Wegner, 1998). Identity negotiation establishes role expectations and accepted behaviors in various interactions and relationships. As an individual negotiates identity, they may experience a feeling of dissonance, or an uncomfortable state in which their beliefs, ideas, or values are seemingly in conflict. Individuals may begin to question their roles and identities. One's sense of identity is constantly within the process of being renegotiated and reformed through interactions with others (Goldston and Kyzer 2009; Holland & Lave, 2001). An individual continuously evaluates interactions which cause them to identify or counter-identify with certain groups or individuals based on how they are seen or accepted (Pozzer & Jackson, 2015). In this way, identity development is both a communicational practice and the product of collective storytelling (Gee, 2001; Gonzalez, 1999; Hall & du Guy, 1996; Sfard & Prusak, 2005). Observing computing identity development as a series of interactions and negotiations suggests that computer science students are active participants within their experiences, moving towards, or perhaps in some cases away from, a computing identity.

By examining the educational experiences and identity development of women and URM students through an identity lens in which construction and negotiation are forefronted, one has the opportunity to explore the dynamic relationship between individual agency and societal constraints (Brickhouse, 2001). Although individuals have agency in their abilities to act freely and independently in their interactions and experiences with computing, their experiences may be defined by structural inequalities that limit those choices and available opportunities. In computing, these structural inequalities may influence the ways in which traditionally marginalized students are able to form and maintain computing identities during their college experiences.

Viewing computing identity development as both dynamic as well as constructed through interactions with others questions the responsibility of educational institutions to create environments which encourage the affirmative construction and negotiation of computing identities. Traditional computer science practices promote narrow identities that may not appeal to a broad range of individuals, causing students to choose between embracing and resisting these narrow identities (Brickhouse & Potter, 2001; Eisenhart & Finkel, 1998). Scholars suggest that enhancing STEM education requires institutions to be attentive to the type of individual that we ask students (e.g. traits, experiences, personalities), particularly women and URMs, to become as they progress through the educational pipeline as these students may be asked to negotiate their identities (Carlone & Johnson, 2007; Ong, Wright, Espinosa, & Orfield, 2011). These perspectives are particularly significant for the investigation of how women and URMs are drawn to or pushed out of the heavily White, masculine computer science discipline. Utilizing computing identity development enables scholars to examine the interactions of students in computing and those individuals and structures around them in order to understand how identities are constructed and renegotiated during the college experience. Furthermore, identity development provides a means to understand the ways in which these interactions and structures marginalize certain populations and hamper computing identity development (Lemke, 2000; Malone & Barabino, 2009; Rahm, 2008).

The Need for Enhanced, Theoretical Analysis of Computing Identity Development

As discussed above, some scholarship has emphasized the importance of identity for students. However, the experiences of computer science students in particular have been neglected in the research agenda until recently (see Kanny, Sax, & Riggers-Piehl, 2014 for a review). Though there is a growing body of literature focused on women and URM students' participation in computing majors, little attention has been paid to the concept of computing identity development and efforts to affirm diverse students' computing identities. This review will discuss what is known about computing identity, as well as related concepts, including students' sense of belonging in computing and computing's disciplinary identity. We build upon this literature to demonstrate the need for an intersectional approach to computing identity theory which can enhance our ability to create more equitable computing environments.

Computing identity. There is a dearth of research that examines the concept of computing identity, as a distinct concept from STEM identity. Dempsey, Snodgrass, Kishi, and Titcomb, (2015) examined a number of factors that contribute to the intention of students enrolled in an introductory computing course to continue in the computer science (CS) major. They found that computer science identity, which the authors defined as the extent to which "the student sees themselves as a computer scientist" (p. 1), had the strongest correlation with students' intention to continue in a CS major among the variables included in the study. Importantly, the authors also found a significant gap between men's and women's CS identity, such that the mean score for men's CS identity was significantly higher than women's CS identity. This study examined a parallel variable related to science identity. The authors found no significant correlation between students' ratings of their science identity and their intent to continue in a CS major, nor did they find a gender difference. The authors argue that "these results lead to the initial conclusion that even though CS has "science" in its name and is considered a STEM discipline, computer science seems to be viewed differently than other sciences" (Dempsey et al., 2015, p. 4). Their conclusion reinforces the role of structural environments and socialization in identity development. As a socially constructed entity, computing identities are necessarily different from general science (or STEM) identities. In turn, students' experiences in computing are central to developing a distinct computing identity.

Recent scholarship from Peters and colleagues emphasizes the importance of first-year students' experiences in computer science and IT, suggesting these experiences are forces that inform one's computing identity (Peters, 2014; Peters & Pears, 2013; Peters & Pears, 2012; Peters, Berglund, Eckerdal & Pears, 2014). Peters' (2014) work demonstrates that computing students' experiences in first year courses both shape their ability to see themselves as computer scientists as well as their continued interest in the field. In particular, Peters (2014) found that students' persistence in computing could be threatened when they had experiences in computing that they could not integrate into their personal identities. For example, when students encountered stereotypes about computing (e.g., the "hacker/geek" stereotype) that did not align with their personal identities, they experienced dissonance and were more likely to leave computing.

These studies provide several useful insights upon which future research should build, as the findings from these studies may not be generalizable given that the samples were limited to students from single institutions. Still, given the importance computing identity appears to play in students' persistence in computing, future research should investigate the role that computing identity may play in explaining the discrepancies in opportunities, attitudes, and placement in computing degree attainment. Additionally, as Dempsey et al. (2015) suggest, the finding that science identity and computing identity are distinct concepts, should be investigated further. This finding lends credence to the idea that scholars cannot equate computing identity with science or STEM identity. Further, while these studies have considered gender, they have not investigated the intersectional components of identity and how their gender and racial/ethnic identities inform computing identities. As such, new theories need to be developed that adequately explore, define, and contextualize computing identity.

Sense of belonging. A concept related to computing identity is students' sense of belonging in the computing field. Sense of belonging may be defined as "students' sense of being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom setting and of feeling oneself to be an important part of the life and activity of the class" (Goodenow, 1993, p. 25). Both concepts rely on how the individual views oneself in the context of an academic environment as well as how relevant others, such as peers or instructors, view that individual. Research on sense of belonging within computer science has found that a strong sense of belonging in the field can help students overcome concerns about their abilities to succeed in computer science and allow students to persist in the major (Veilleux, Bates, Jones, Allendoefer, and Crawford, 2012).

As discussed previously, the environment plays an important role in fostering students' sense of belonging in computing. One study found that the physical environment of a college computer science classroom and the presence of computer science stereotypical objects, such as posters about video games, affected students' sense of belonging in computer and impacted their interest in the field (Cheryan et al., 2009). Thus, the authors explain that these environments "come to broadcast stereotypes of a group, which in turn can deter people who do not identify with these stereotypes from joining that group" (Cheryan et al., 2009, p. 1045). Because stereotypes in computing are closely linked to gender, such stereotypes play a key role in shaping men's and women's interest in computing (Margolis & Fisher, 2003). Women who hold negative stereotypes of computing find the field less appealing (Beyer, Rynes & Haller, 2004). Stereotypes about computing (e.g., male hacker/geek stereotypes) may make it difficult for women and URMs to see themselves as computer scientists, and thus, be deterred from pursuing a computing degree. Indeed, students' views of computing stereotypes play a role in how students' determine if they "fit" in computing and make decisions about their continued participation in the field (Lewis et al., 2016). Although previous research has established that the connections between sense of belonging, environment, and stereotypes play a crucial role in computing student experiences, these elements are not well-represented in current theoretical framing and point to the need for a more in-depth discussion around an intersectional approach to computing identity theory.

Computing disciplinary identity. Computer science is a relatively young discipline, and during its short history, what it meant to be a "programmer" has evolved from a clerical position predominately filled by women to a male-dominated profession reserved for smart, creative types (Ensmenger, 2010). Ensmenger's characterization of the computer science field aligns with the discipline’s classification in person-environment fit theories, such as Holland’s Theory of Career Choice (1997). Holland posited that students chose a major (or career) based upon their personalities and, in turn, their major or career choice is reinforced by norms and characteristics of their chosen field. In Holland’s theory (1997), computer science is classified as an investigative environment, which focuses on analytical and scientific activities and values scholarship, intellectualism, and scientific rigor. Notably, investigative environments are usually male dominated (Smart, Feldman, and Ethington, 2000).

The concept of what it means to be a computer scientist is closely linked with the body of knowledge required to be a computer scientist. As a field that was historically comprised of White men, the foundational knowledge of the discipline is gendered (Björkman, 2005; Faulkner, 2001). That is, (White) men’s ways of knowing may be privileged in computing spaces such that “knowing computer science” may not accommodate diverse people or perspectives (Björkman, 2005, p. 14). Hence, the field itself develops an identity, both as a body of individuals and knowledge. These norms and values are reinforced and perpetuated by those with the most power in the discipline, such as professors and more advanced students (Rasmussen & Hapnes, 1991), and then are communicated to prospective computer scientists, as discussed above with respect to students’ sense of belonging in the field. For example, Barker and Gavin-Doxas (2004) studied the learning environment in computer science classrooms and found a prevalence of impersonal and guarded behavior as well as classroom hierarchies that encouraged competition. Classroom environments are one way that students experience the computing discipline. The experiences students have with computing, even from an early age, and the process of acquiring the foundational knowledge of the field shapes the way they think about computing and their computing identity (Hansen et al., 2017; Schulte & Knobelsdork, 2007; Zander, Boustedt, McCartney, Mostrom, Sanders & Thomas, 2009; Wong, 2016).

As a discipline, the culture of computing, which is often seen as individualistic, decontextualized, and unwelcoming to women and URMs, can be seen as problematic to creating equitable educational outcomes. Computing culture may often emphasize working independently without support from others (Waite, Jackson, Diwan, & Leonardi, 2004) and be narrowly tailored to technical aspects rather than contextualized in wider applications or implications (Cech, 2014). Given its unique disciplinary characteristics, it is not surprising, then, that the individuals who pursue computing are different than those who pursue other STEM subfields (Lehman, Sax & Zimmerman, 2017). In fact, research suggests that the characteristics and backgrounds of college students who plan to major in computer science are distinctly different from students who pursue other STEM fields, and the characteristics of men and women who pursue computing majors are also different (Lehman et al., 2017). Thus, it seems likely that their computing identity development will also differ, both between students who pursue computing as opposed to other STEM fields and between men and women who pursue computer science. Despite the unique nature of computing as a field, current theories of science and STEM identity do not account for disciplinary differences that may shape (computer) science identities. Further, extant literature has not investigated differences in how individuals with multiple, intersecting identities may come to view themselves as computer scientists.

Bringing Intersectionality to Computing Identity Theory

Drawing upon the seminal work of Kimberlé Crenshaw (1991) and Patricia Hill Collins (2008), an understanding and willingness to address intersectionality may enhance the way in which we construct computing identity theory and create more equitable educational environments. Intersectionality refers to the individual, intersecting identities that create unique experiences for groups, such as URM women in computing, as well as how larger social patterns and systemic inequities often reproduce inequities for individuals and groups with marginalized identities (Crenshaw, 1991). An intersectional approach to computing recognizes that students experience this context in classed, gendered, and racialized ways (Crenshaw, 1991; Collins, 2008; hooks, 1992). Students may experience the computing environment through the lens of their socioeconomic status (e.g. income, education), gender (e.g. women, societal role), and/or race (e.g. Latino, African American). As a result of the ways that other people perceive these identities, students may also experience marginalization and compounding forms of oppression.

Unfortunately, most of the scholarship on participation gaps in computing focus on gender *or* race/ethnicity, rather than investigate the intersectional nature of the experiences of women and URM subgroups in computer science (e.g., Cohoon & Aspray, 2008; Hewlett, Sherbin, Dieudonne, Fargnoli, & Fredman, 2014; Margolis, Estrella, Goode, Holme, & Nao, 2010). Such fragmentation has not allowed for a complete contextualized understanding of the complex identity development of these students. This highlights a significant gap within the literature and theory development which has, until recently, failed to consider the dynamic relationship between computer science and intersectional identities. This perspective may deepen the understanding of computing identity development and forge new paths towards intersectional theory building.

Further research and theory-making which addresses computing and intersectional identities is needed in order to obtain a more nuanced view of the computing identity development of women and URMs. Beliefs about who can and cannot succeed in computer science may be particularly important to URM women's success in the field. Research focused on STEM fields in the aggregate has found that identity development influences STEM interest and persistence, especially for women of color (Brickhouse, Lowery, & Schultz, 2000; Carlone & Johnson, 2007). For example, women of color in computing may not only experience sexism based on stereotypes about women in computing but may also experience racism based on stereotypes about URMs engaged in computing (e.g. Carlone & Johnson, 2007). And, although this paper forefronts the need to address the intersectionality of racial, ethnic, and gender identities within computing, we also acknowledge that there are a multitude of identities which may cause students to experience marginalization in their educational environments (e.g. class, sexual orientation, disability status, religion). The intersections of various identities can create multiple layers of discrimination and marginalization that may discourage diverse students from pursuing computing and force them to leave the discipline or higher education altogether. Therefore, more robust intersectional computing identity theory is needed in order to understand the individual experiences of students, account for the complexities of their experiences, and prevent marginalization.

Through taking an intersectional approach, identity theory could assist stakeholders in questioning the culture of computing and recognizing who is marginalized by that culture (Carlone & Johnson, 2007, Jackson & Pozzer, 2015). For this reason, theory must consider both the individual-level identity experiences of women and URMs in computing and the larger systems of inequalities (Collins, 2008; Crenshaw, 1991).Through questioning the culture of computing, identity theory moves beyond understanding how identities are developed to critiquing and improving the often problematic cultural environment in which those identities are formed and continuously reified (Jackson & Pozzer, 2015). Addressing this problematic cultural environment would push towards deconstructing larger systems of inequality by acknowledging issues such as racism, sexism, and classism as structural barriers to success. Such work would fill a needed gap in the literature as well as provide a theoretical basis for understanding how researchers, administrators, and policy makers can best enhance the computer science educational pipeline to include a diverse range of perspectives.

Implications of the Argument

The lack of theory specifically addressing the complexity of identity development within computer science, particularly for women and/or URM students, is problematic for several reasons. First, scholars who investigate participation gaps in computing fields may be making decisions in their research that are not theoretically grounded. Theory may be overlooked in part because the scholars focused on broadening participation in computing come from myriad disciplines (e.g., education, economics, sociology, psychology, business, and computing, to name but a few), and each of these disciplines has different norms around the use and application of theory in research. Further, as the individuals doing this work come from diverse disciplinary backgrounds, there is not a shared knowledge base around a set of appropriate theoretical frameworks. We have argued for identity theory as a useful guide for scholarship focused on issues of diversity in computing. Yet, even though scholarship in this area is growing, the analytical lens of identity remains an under-researched area. This may be particularly problematic when considering the influence that field-specific identity development has for women and URM students. Traditional methods of analysis may miss key indicators for success and retention when identity formation is neglected.

Next, even when scholarship does rely on theories of identity, the fact that these frameworks tend to consider STEM in the aggregate may mask nuanced issues in computer science, which compromises researchers' ability to fully understand the discipline's identity development issues and hinders our ability to improve persistence and diversify the computer science workforce. Given the emergence and growth of computer science careers, student identity experiences may differ greatly from other, more established areas of science.

Finally, when we do not account for gender, race/ethnicity, and other intersectional identities in our research and operating frameworks, we risk alienating students who do not identify with major groups in computing disciplines, leading to a failure to understand the experiences of students in this discipline. Failing to understand their unique, intersectional experiences may mean that colleges and universities subject students to contexts and experiences that force students out of computing programs and careers. While some may see this as an individual, student-level issue, systematically marginalizing these students, both in lived experiences and in theoretical considerations, can have far-reaching repercussions on our ability to develop the next generation of diverse computer scientists.

The trajectory of scholarship on students' participation and experiences in STEM fields is increasingly specific, as scholarship has identified distinct differences between the STEM subfields (Kanny et al., 2014) as well as between groups of students within those disciplines (Lehman et al., 2017; Sax, Kanny, Riggers-Piehl, Whang & Paulson, 2015). However, theories of identity have not kept pace. There is a need for identity theories that disaggregate by STEM subfield and take into account intersectional identities. Disaggregation and intersectionality are critical for understanding identity development in the field of computer science given its growing need for recruitment of women and URMs (The White House, 2016), and the differentiation of computer science students from those in other STEM fields (Lehman et al., 2017). Theory specific to the computing field is, thus, of particular importance.

Further, as new computing theories emerge, they must be tested and evolved for different contexts, such as historically Black colleges and universities (HBCUs), Hispanic serving institutions (HSIs), and community colleges, as well as for different subgroups of women and URM students to ensure inclusivity and capture the impact that environment and disaggregation has on computer science theory. Finally, as theory specific to computer science is developed, faculty, staff, and administrators must implement the knowledge gained from such theory in practice in order to better support students and the development of computer science identities, thereby increasing the number of computer science majors and those entering the computing workforce.

Applying Intersectional Computing Identity Theory to Practice

Integrating established concepts such as identity research, intersectionality, and computer science education enables us to critically analyze identity development within the computing cultural and shift towards a more inclusive environment. Improved, intersectional computing identity theory will provide valuable information about computer science classroom experiences; faculty, tutor, and peer interactions; and the campus climate and norms which can illuminate key experiences for women and URMs. Through building better theory, educational stakeholders will be able to address inequitable educational environments, enhance computing identity development and, ultimately, improve undergraduate persistence and graduate school and/or workforce outcomes for women and URMs.

Classrooms. Computing identity theory could be instrumental in building a theoretically grounded understanding of best practices for developing identity within the college or university classroom setting. Enhanced theory could assist faculty in understanding how the framing of computer science courses influences the way in which students feel as though those classes have helped them to develop computer science identities. For instance, introductory classes framed with concepts of preparing future computer scientists for the field may have a positive influence on students who are struggling to see themselves in this role. In addition, advanced computing classes might be framed as immersing students into the computing field through a series of scaffolded exercises meant to build a sense of identity and connection with computing careers. In this way, a diverse group of students begin to see themselves as computer scientists and become part of the fabric of that environment rather than being marginalized by it.

In addition, improved computer science theory might also improve the way that faculty build upon best-practices to encourage identity development. Greater investigation in this area might reveal how faculty members can best leverage culturally relevant problem-solving activities and simulations for identity development in the classroom. Furthermore, an intersectional approach might encourage faculty to understand how issues of privilege and power manifest in the classroom as a result of how computing identities are negotiated between individuals during college.

Advising and Mentoring. Understanding the nuances of intersectional computer science theory alongside the processes of advising and mentoring may encourage faculty and staff to modify the ways in which they interact with students. From this standpoint, the actions of advising and mentoring become a process of building computing identity and encouraging meaningful exchanges. Stronger theoretical grounding and consideration of intersectional identities could become a guide in creating more equitable policies, developing critical milestones of achievement, and setting goals for computing student engagement. Greater theoretical understandings in the area of computing identity development may also influence the ways in which faculty and staff members structure their conversations with students and advice for career success. Attention to identity development, rather than simply persistence, might enhance the experiences of women and URMs in computing by centralizing discussions of identity, rather than stifling those discussions. For faculty and staff mentors, a focus on developing computing identity provides a way in which faculty to reflect on their own intersectional identity experiences and create a space for sharing those experiences with students and encouraging students to examine their own experiences.

Applied Learning and Problem-solving Experiences. Although scholarship has addressed best practices related to applied learning and problem-solving experiences in computing, these best practices have not been fully examined in terms of how they relate to the development of a computing identity. A theoretically grounded look at how these experiences influence identity development could determine how certain activities are more or less influential for the identity development of a diverse computing workforce. This understanding might support more nuanced discussions around pedagogy choices and the influence of one's own identities in shaping classroom learning and outcomes. Furthermore, structuring applied learning and problem-solving experiences around theoretically-grounded, intersectional identity development provides a systematic way to ensure that all students are working towards the development of a computing identity.

Department-level Curricula and University-level Initiatives. Enhanced, intersectional computing identity theory may be an opportunity for structural and cultural changes at the department and university levels. Approaching structural change from this perspective might require stakeholders to change fundamental processes within the department or university. These structural changes can help prepare for policy implementation and broader cultural change. Cultural change is time-intensive and requires greater attention to understanding the current internal and external computing environment. Stakeholders must not only examine the current culture but must gain a shared vision of the mission and purpose around promoting computing identity development. From here, the group must identify what changes are to be made in order to support this environment.

Identity development as a lens demonstrates that each individual, and marginalized group, is a partial manifestation of the environment that the institution has created. If institutions wish for more women and URMs to be in the computing field, they might consider an intersectional approach to addressing key levers for structural and cultural changes. Understanding the computing experience as an intersectional identity development process means that stakeholders make a commitment to understanding and honoring the various identities that students bring with them and scaffolding computing experiences that develop computing identities. Rather than forcing students to assimilate into current computing cultures, which may be in toxic in multiple ways, this invites institutions to question their cultures, policies, and procedures to understand how those environments need to fundamentally shift in order to prevent marginalization.

At the department level, improving what we know about computing identity theory may encourage administrators and faculty to evaluate and revise curricula in order to meet the developmental needs of students. Better theory could point to course content, structure, and pathways that might be altered in order to address the intersectional needs of women and URMs within computing. At the university level, theoretically-grounded intersectional approaches could lead to a more cohesive approach to improving computing identity development and a more intentional plan for supporting students from diverse backgrounds. Initiatives focused on computing would improve return on investment, elevate the institution's profile among peers, and demonstrate an innovative approach to supporting the future's diverse group of computer scientists.

Conclusion

Researchers and practitioners have increasingly focused on efforts to recruit and retain more women and URMs in computing fields. Scholarship on computing identity can help inform these efforts, but given the unique nature of computing disciplines relative to other STEM fields, an extension and intersectional approach to current frameworks is needed to more accurately capture computer scientists' identity development. Drawing on the limited existing literature on computing identity and the theory of intersectionality, this paper advances an argument for evolving computing identity theory to more specifically address the dynamics of computer science and explore ways in which computing identity theory might inform research and practice. Armed with a more precise understanding of how individuals in computing come to see themselves as computer scientists, the field will be better equipped to not only to attract diverse students but create environments which support these students throughout their educational journeys.

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