What is a Computer Scientist?: Unpacking the Ontological Beliefs of Black and Hispanic Female Computing Students

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ABSTRACT

Underrepresentation of Black and Hispanic women in computer science is a long-standing problem that looks bleak at every level - undergraduate and graduate. This is prompting scholars to explore reasons for these low participation rates. One framework used to understand participation and persistence in STEM fields is identity. Prior work in computer science education suggest that identity is a strong indicator of persistence in these fields. However, it is hard to understand students' perception of identity without also understanding ontological beliefs with regards to a computer scientist. In this study, we explore the nature of a computer scientist. Guided by social identity theory, we designed a study that asked students to describe their definition or ontological belief of what constitutes a computer scientist in contrast to their ability to ascribe a computer science identity to self. Leveraging qualitative methods, we interviewed n= 24 women in computer science (Black and Hispanic, undergraduate and graduate students), in order to explore the role their ontological beliefs had on their computer science identity salience. The research questions guiding this work are: (1) How do Black and Hispanic women describe or define computer scientists? (2) What impact does this definition have on Black and Hispanic women's ability to claim a computing identity? Results suggest that the wide variation in definitions has a negative impact on computer science identity salience. The findings from this work suggest that computing should consider the impacts of the current messaging of what constitutes a computer scientist.

CCS CONCEPTS

• **Social and professional topics → Computer science education**.

KEYWORDS

Computing education, Computer science education, Undergraduate curriculum; Broadening participation

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1 INTRODUCTION - THE PROBLEM

Black and Hispanic women have been and are currently a massively underrepresented population in computer science (CS), making up only 2.3% and 1.9% of undergraduate degrees awarded in the U.S., respectively [22]. With a growing demand to broaden participation to meet the need of a growing CS workforce [14] scholarship has sought to understand the lack of involvement and find pathways for more underrepresented populations to succeed in a CS education. One such approach to understanding and addressing the lack of diversity in computer science has been the exploration of identity, more specifically computer science or computing identity, in relationship to persistence rates [12, 21]. Identity theory is largely dependent on students' self-concept related to their ability to see themselves as being (in this case) a computer scientist. However, in order to ascribe this identity to self they must have some definition or understanding of what constitutes that discipline. This is their ontological belief of a computer scientist. If we can understand their ontological beliefs we can begin to understand their computer science identity salience (or lack thereof), and thus better understand engagement and persistence of Black and Hispanic women. This study was designed to explore students' ontological beliefs about what a computer scientist is and whether they self-ascribe that identity to themselves by answering the following research questions:

(1) How do Black and Hispanic women describe or define computer scientists?
(2) What impact does this definition have on Black and Hispanic women's ability to claim a computing identity?

2 RELATED RESEARCH

The body of literature surrounding ontological beliefs of individuals in computer science education has largely been centered on discourse and/or stereotypes about what constitutes a computer scientist [25]. Wong, [25] reported that these stereotypes can threaten a students' belief about what can be or should be a computer scientist. For instance, if a student believes that a computing professional is "innately clever, committed, and analytical" and this individual finds this to be congruent with their own self-concept, then they are likely to ascribe a computer scientist identity to self [25]. However, individuals that perceive that they do not possess these qualities will struggle to adopt this identity. A study that focused on young computer-savvy K-12 students found that because of this dissonance between their perceptions of computing (shaped by stereotypes; or their ontological beliefs) and their self-concept claiming a computer science identity was perceived as unattainable. Vakil [23] identified similar trends when exploring political identities, ontology, and computer science education with K-12 students that resulted in students rejecting computer science due to perceptions that it is "antithetical to justice and human rights concerns." Students that centered those values saw an incongruence between their ontological beliefs of computer science (and engineering) and their self-concept of being conscious of social justice [7]. Given that marginalized populations are often communally-minded and oftentimes, lead the movements for social justice [5], this lack of identity confluence could push them away from computing rather then attract. Kinnunen [11] suggested that this conceptualization of identity and how it relates to computer science, not only has implications for engagement of present perceptions of self in computing but also their future selves or their persistence in the field. This can be particularly problematic when we consider the gendered and racialized nature of stereotypes associated with the computing profession. This prior work lays the foundation for further exploring the ontological beliefs of students and their identity claims, in particular women of color.

The idea of computer science identity has been explored previously by many scholars [12, 21]. In particular, Dempsey et al [4] described computer science identity as an identity that a person can self-ascribe to oneself - a computer scientist label. The authors found that CS identity had a positive correlation with a student's persistence in a CS degree and their completion [4]. The authors also found that men typically scored higher on the CS identity instrument while women scored lower [4]. However, this study did not explore the participant's definitions or ontological beliefs of a computer scientist. Given the gap between men's and women's CS identity and very little understanding of their ontological beliefs about a computer scientist, we seek to uncover in our work what Black and Hispanic women in our study believe a computer scientist to be. We also seek to understand the impact that these definitions have on their ability to align themselves with an affirmative CS identity. Without a firm understanding of what minoritized populations conceptions of a computer scientist are, it will be unlikely to bridge the gap in the affirmation of a CS identity.

3 THEORETICAL FRAMING

This study was framed by social identity theory, more specifically role identity in relation to ontology. Role identity refers to the parts or roles of a self, constructed by meanings that a person attaches to the many roles they play in their world [20]. In the context of this study the role identity we are talking about is a *disciplinary identity* - computing science identity. Prior work in computer science education have described disciplinary identity as the ways that students describe or report their interest, performance, perceived recognition, and (more recently) sense of belonging in a discipline [21]. In short, claims to a disciplinary identity can be used to predict a students' intentions to remain engaged in the discipline or occupation. When developing the interview protocol, we asked the participants directly if they saw themselves as computer scientist to determine if they ascribed the identity to self. But in order to better understand their identity we must also understand how they define that identity or their ontological beliefs as it relates to computer science - What is a computer scientist?

In order to understand their beliefs with regards to what a computer scientist is, we leveraged work related to ontological beliefs. Ontology is defined as the nature of being or a shared understanding [13]. In the simplest form, it is how we define something. For the purposes of this study it is how one defines being a computer scientist. If identity is the self-ascribing (or being ascribed) of a role in a discipline, ontology is how one defines or describes that role. Prior scholars have drawn similar connections, for example studies that have elicited perceptions of computer scientists of K-12 students that explore their ideas, ontological beliefs, and (unfortunately) stereotypes related to computer scientists [6, 8, 9]. While this work gives us insight into the perceptions of students not yet pursuing an occupation in computer science it gives us little insight into how current computer science students define their future occupation and if/how this influences their ability to ascribe this identity to themselves. Furthermore, there is limited work on perceptions and ontological beliefs of those underrepresented in computer science - women and people of color, this study fills that gap.

Heeding the call from prior scholars to explore computer science identity with considerations for intersectionality [15, 16] in this study, we asked Black and Hispanic women in computer science to speak to: their ontological beliefs of computer scientists and if they ascribed the identity of computer scientist to themselves. For this work, both social identity theory and ontology were used as guiding frameworks that shaped the interview protocol; and as interpretative frameworks for understanding the relationship between the two concepts - identity and ontology. The objective of this work was to understand participants' self-identification with a computer science identity but also insight into their beliefs of what a computer scientist was, to determine if their ontological beliefs were a barrier to computer science identity attainment.

4 METHODS

This study is part of a larger inquiry into the pathways to and through computer science of Black and Hispanic women. As such, the data consists of a series of interviews conducted from 2017 - 2020 of twenty-four participants that self-identified as a woman, Black and/or Hispanic, and pursuing a degree (undergraduate or

graduate) in a computer-related field - namely, computer science and computer engineering.

The method used for data collection was an in-depth sixty to 90 minute interview that explored motivations for pursuing computing as an occupational pursuit and experiences in computing. In-depth interviews were selected as the mechanism for data collection because they often result in rich data that can provide insight into often complex topics [19]. To aid in the interview, a semi-structured interview protocol was developed that derived questions from the theoretical frameworks (described above) but also had enough flexibility to allow for deeper exploration into topics that emerged in the interview. The protocol questions that were of particular interest to this study were: *How do you define a computer scientist?* AND *Do you consider yourself to be a computer scientist?*

4.1 Positionality Statement

The research presented in this paper was conducted by four researchers. The third and fourth authors were critical in the data collection phase of the project. They both self-identify as Hispanic women and were also computer science undergraduate students. Their proximity to the participants (in academic standing and gender and ethnic identity), we suspect helped the participants be more comfortable in their recounting of their experiences in computer science [1]. They conducted all of the in-depth interviews with the participants. Likewise, the first and second author lead the analysis of the work. Due to their engagement with the data and the potential for bias, we are providing positionality statements for both.

The first author is a Latino male who has studied computer science at the undergraduate level and is currently studying computer science education at the graduate level. The author is conscious of his own experiences as a male computer scientist (outsider) and has taken that perspective into account during data analysis. The second author is a Black woman engineer that studied computing in both undergraduate and graduate school. As such, she acknowledges that previous experiences in all of the domains influence the interpretation of the findings (insider). The first author developed the interview protocol and engaged in the data analysis with mindfulness and deliberate attention to intentional practice of reflection.

In the interest of quality, the research team incorporated and invoked the Q3 - qualifying qualitative research quality framework - during the research project life cycle from design, data collection, data handling, and now in the communication of the findings [24]. As such the research team was deliberate in our efforts to ensure theoretical, procedural, communicative, pragmatic, and ethical validation as well as process reliability.

4.2 Sample Population

The participants for the study were recruited in three different phases. The first phase was for a pilot study of the interview protocol in Fall 2017 at a large minority serving institution (MSI). The second phase was from graduate students in Fall 2017 from a predominately white institution (PWI). The third phase was from a nationally dispersed call for participation of undergraduate students from all over the country and from a mix of Historically Black Colleges and Universities (HBCUs), PWIs, and a Hispanic Serving Institution (HSI). All 24 of the participants self-identified as women, Black and/or Hispanic, as pursuing a degree in computing, and were from all stages of degree attainment from freshman to seniors and from early graduate students to nearing completion. The breakdown of participants (self-identified) included: 18 undergraduates, 6 graduate students, 3 Hispanic-White, 3 Hispanic, 2 Hispanic-Black, 11 Black/African-American, 5 Latinx, 22 computer science, and 2 computer engineering.

The participants were solicited through snowball sampling, in which one participant is identified as meeting the selection criteria and then they recommend another participant that meets the selection criteria [2]. It should be noted that such snowball sampling often makes it hard to make inferences about populations. Each potential participant candidate was sent an email asking for their participation, followed by the signing of consent forms, and participating in an IRB approved interview. The interviews were audio recorded, subsequently transcribed by a third-party, proofread for accuracy, and redacted.

4.3 Data Analysis

After the data was redacted, the answers to the two interview questions (see Methods) were exported into a spreadsheet and organized into columns with the participant's pseudonym, quoted response to the interview questions, and eventually codes. Two coders read through each participant's response to initially create codes using *in vivo* coding [17]. The two coders then met and discussed the initial codes to reach *intercoder agreement* to help ensure agreement upon analyzed codes [17]. As the responses were open ended and subject to interpretation, being able to have agreement among codes was crucial to ensure consistency and a shared understanding during data analysis. As the purpose of this study was to understand the role that ontological beliefs have on computer science identity development, *in vivo* coding allowed for the participants' words to create the codes and mitigate the impact of us, as researchers, imposing our meaning onto their responses [17]. After reading a response, a phrase or word was selected from the quote that best represented the response.

Once codes were assigned to all responses, the codes were organized into concept maps. Concept maps are one strategy for reducing the magnitude of qualitative data, visualizing *themes*, and establishing relationships between the themes [3]. The intent of the study was to determine if there were connections between the ontological beliefs of our participants and their identity as a computer scientist; a concept map provided the tool for developing a visual representation of these connections between the participants.

For the original concept map, we created rectangular nodes for each code from the initial *in vivo* coding and then grouped near other codes that were either similar or identical (see Figure 1). With the codes grouped, broader themes from the nodes were developed and represented as a diamond shape (in the concept map). Connections were then drawn between the broader themes and *in vivo* codes using either solid or dotted lines. A solid line represented a strong link between the theme and the *in vivo* code, meaning there was evidence in the quote. A dotted line represented a loose connection to the broader code. Some codes are shown in a cloud shape as they were more nebulous and were interpreted to be

a bridge between two different codes, and as such, were connected with a dotted line.

Three additional concept maps were then created. The second concept map was created to illustrate the participants that articulated an affirmative computer science identity (not shown due to page constraints). This concept map contained the codes and the participants whose responses fell within those codes. The third concept map demonstrated the connections of those participants who did not ascribe themselves the computer scientist identity (not shown). The fourth concept map was created to show the overlap and disparities between the two ontologies (see Figure 2). The overlapping codes were placed in the center with those having an affirmative computer scientist identity on the left of the code and the non-computer scientist on the right (see Figure 2). The codes that did not overlap were placed on the far left if they aligned with a positive computer scientist identity, and the far right if they aligned with a non-computer scientist identity.

4.4 Results/Findings

Research Question 1: How do Black and Hispanic women describe or define computer scientists?

Through the use of concept maps we were able to distill the participant definitions down to *nine themes*: Software development (professional), technical expertise, problem solver, theory, innovation, passion for technology, math and science foundation, basic CS knowledge, and ubiquity.

Oftentimes, participants discussed computer scientists in terms of *software development*. Meaning they viewed a computer scientist as a person who creates technological artifacts, in the form of software, to solve problems. Karen went as far as to say that, "If you want to be considered a computer scientist or a programmer, that would encompass you being able to build software to accomplish a specific goal, whatever the goal is" (Karen). Based on Karen's ontological beliefs a computer scientist and a programmer are synonymous and are only attained if you could develop software.

Many participants described a computer scientist as a *problem solver*. They often referred to a computer scientist as someone who is leveraging technology to solve problems.

> "But a computer scientist, well in my eyes, is someone that is able to think logically and build something that can then help or, I don't know, develop something else at the end of all of it. So like a critical thinker that … Yeah a critical problem solver" (Tasa).

Within this categorization of problem solver, we also saw that a participant had further specified that a computer scientist is someone with *technical expertise*. We see this as a clarification of a problem solver and puts a specific requirement on the computer scientist to draw from a set of computer science skills to solve problems in concert with critical thinking skills. "So, I think computer scientists are people who have to use their technical expertise to solve problems because I find that that's what we all are doing, is solving problems based on our technical background" (Avatar).

Some described a computer scientist as being beholden to *theory*. A computer scientist was seen as using theory behind computing that is applied in other disciplines.

> "Computer scientists I feel more like the theory, I don't know, kind of like the theory of computing or software development- does it focus on that and we [computer engineers] create new ways for us to use computers to solve those problems" (Anya).

Others had determined that a computer scientist was an *innovator*. Someone who is focused on creating new and novel technologies. "A computer scientist, to me, is anyone that wants to innovate and wants to innovate using either hardware or software, of course, like coding, but anybody who just wants to program in reality" (Ann).

Passion for technology was another way to describe a computer scientist. A person who has a desire and drive to use technology to find solutions to problems.

> "My definition of a computer scientist is ... I'm trying not to have the world ruin this definition. It is a person with a passion that's willing to utilize technology to acquire that solution that I'm talking about earlier. So it doesn't matter if you have a degree, it doesn't matter your gender, your ethnicity, do you like playing with technology? Do you want to use it? You're a computer scientist" (LaTanya).

Meanwhile some participants made the title computer scientist dependent on having a *foundation of Math and science* or *Basic CS knowledge*. A computer scientist was described as someone having a firm understanding of mathematics and science in general, or applying math in the realm of computer science.

> "I think it's kind of like one and the same, computer scientists to me is not necessarily somebody who codes on computers all day long, or somebody who is creating new chips or new hardware related things or anything new really created for computers, but anyone who really takes those skills that come with computing and learning the foundations of computer science and math and taking those skills and applying it into some other practice" (Shae).

Likewise, CS knowledge meant that they have a firm understanding of the fundamental principles of computing. "A computer scientist or computer engineer is someone who has basic knowledge about computer science" (Freedom).

Computer scientists were also described in terms of the *ubiquitous* nature of computing - meaning they believed that computer scientists were able to use their technical abilities to go beyond the boundaries of computer science.

> "I've done like research with computer surgery, using robotic arms to simulate a surgery, then I've just made apps or designed websites, and I just feel there's so much separate branches of computer science that it's hard to say what computer science is to me, because I think it's just used everywhere. It's like saying what it's not. It's used everywhere. I just think computer science is too versatile to define" (Charlie).

All of these definitions of computer scientist yielded varying degrees of computer science identity salience amongst the participants. As such, we used the results of the final concept map (Figure 2) to

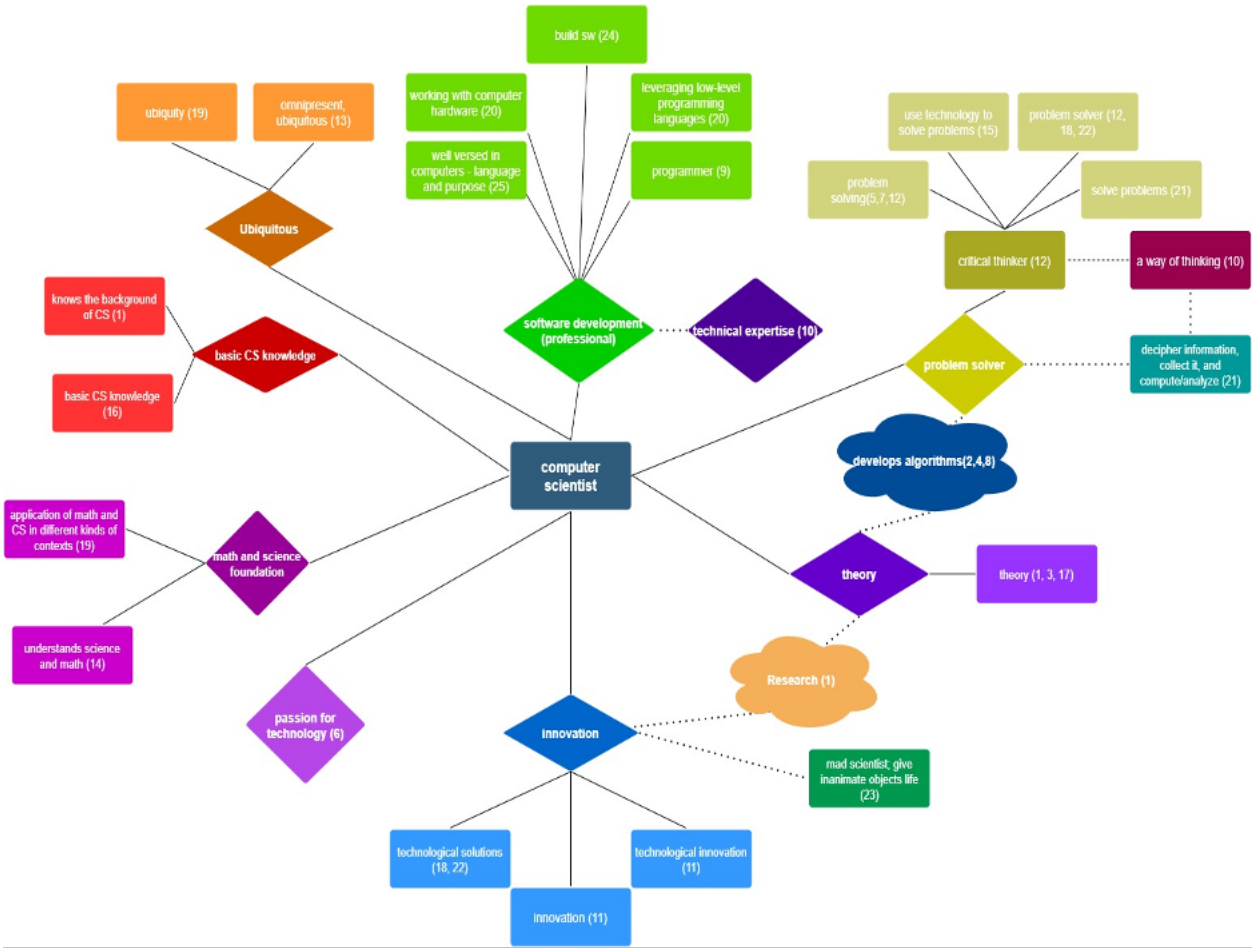

Figure 1: Initial concept map with themes developed through *in vivo* coding cycle

help us determine if there were patterns amongst ontological beliefs of a computer scientist and computer science identity salience.

Research Question 2: What impact does this definition have on Black and Hispanic women's ability to claim a computing identity?

There were 24 participants of which 3 did not answer the question related to identity, 10 claimed a computer science identity, and 11 did not claim the computer science identity. In analyzing the overlapping codes of (Figure 2) it can be seen that there are fewer codes present in the positive computer scientist identity as opposed to the non-computer scientist identity. These fewer codes, however, contain more agreement between those participants who ascribed the computer scientist identity to themselves. This can be interpreted as having a stronger and more consistent definition of what a computer scientist is within the affirmative group. When compared to the non-computer scientist group, there are more disparate definitions of what it means to be a computer scientist. There are far more codes that contain only one or at most two participants. This abundance of codes and lack of agreement reflects a looser and variable understanding of what a computer scientist is.

5 DISCUSSION

Prior work suggests that ontology is important for identity development and salience [23, 25]. That work has largely been focused on how stereotypes and discourse of K-12 students influences their ontologies or perceptions of computer science. These ontological beliefs can, at times, dissuade them from engaging in computing beyond their K-12 exposure [7]. This is largely because those ontological beliefs about computing formed by stereotypes can be in conflict with one's personal identity and thus precludes them from ascribing a disciplinary identity to self [7]. The results of this study build on this work by providing insight into the ontological beliefs of Black and Hispanic women currently enrolled in a computer science or computer engineering degree program. Furthermore, it sheds light on the mixed-messages or lack of coherent messaging equated with computing or computer science. The question - what is a computer scientist? - was not easily answered or understood even by those enrolled and pursuant to this occupation. The variety of ontological beliefs led to mixed results with regards to identity salience. Despite the fact that these women were actively enrolled in computing during the study and persisting (having progressed

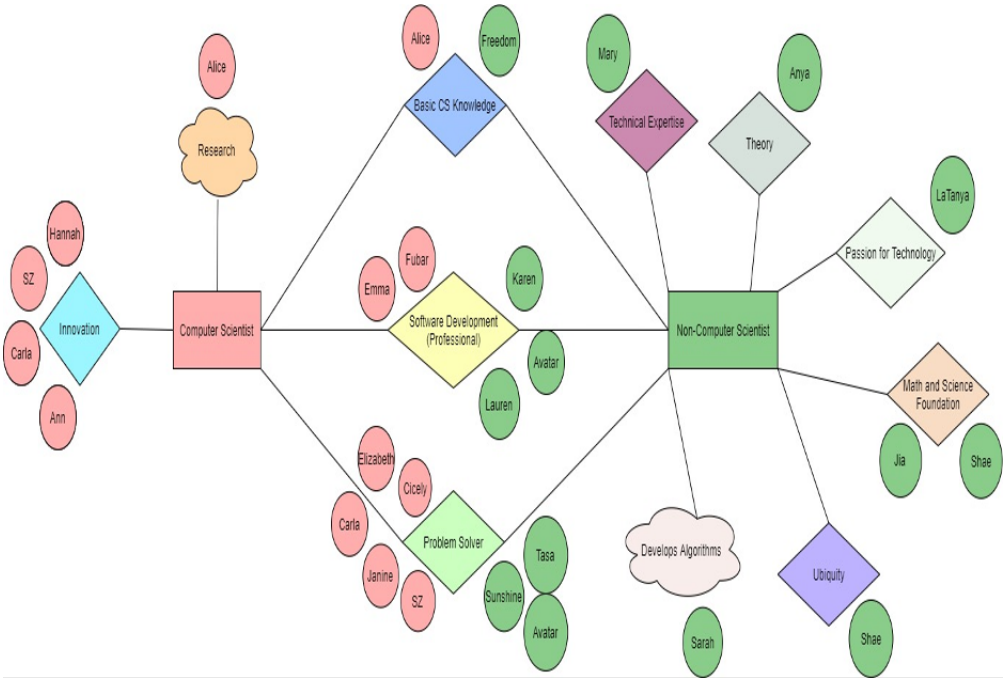

Figure 2: Codes mapped with all participants and the overlap and divergence in codes

beyond the second year of computing and in some cases in graduate school) they were mixed in their claims to a computing identity.

In analyzing the definitions given by the participants in relation to their claims to a computer science identity, we observed that the participants were split in their claims to a CS identity. This left us with two interpretations: (1) given the persistence of these women perhaps identity was not as critical as we were led to believe by prior literature for our population; and (2) the more abstract the definition, the less likely the students were to ascribe an identity to themselves. The women that claimed the identity had what we will call more *concrete* definitions - e.g., software development, problem solver; while those that had more *abstract* conceptualizations - e.g., theory, ubiquity were less likely to claim an identity. They could not seem themselves as embodying the abstract conceptualization they had of a computer scientist and thus were reluctant to claim a computer science identity. This inability to see a congruence between self and their own ontological beliefs made it hard for them to state with confidence that they were a computer scientist. This is consistent with literature that cites lack of role models as a barrier to participation in some fields [18].

In spite of this lack of claim to a computer science identity, these women were persisting. Persistence being defined as making it past the treacherous introductory programming sequence, where students are more likely to leave [10]. This brings to question the applicability of disciplinary identity as a means of evaluating persistence for Black and Hispanic women. While it may be a predictor for many it does not adequately explain the persistence of these women in computing.

6 LIMITATIONS

The study is limited in that it gives a small snapshot into the understanding of ontological beliefs of understudied populations. Future work should include more students and should further explore the motivations for engaging and persisting of these women in computing. Even though we asked them about their definition of a computer scientist a further exploration should include a probe into why these women hesitate to ascribe a computer science identity to self. What exactly gets in the way of their claims to a computer science identity?

7 CONCLUSION

From this work, we have some insight into the ontological beliefs of Black and Hispanic women in computer science. We also learned that ontological beliefs centered on abstract understanding of a computer scientist, may serve as a barrier to claims of identity. There appears to be an incongruence between identity and persistence of this population. If they are in computer science and persisting but do not see themselves as computer scientist, why is that? What identity do they ascribe to themselves? And does it even matter? Should we want students to see themselves as computer scientist? Is it necessary to have to abandon their self-conceptions to conform to a norm in computer science? If so, should we (as a discipline) aspire to an identity or ontological belief computer science that is more inclusive and thus can be ascribed to many?

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