Journal of Computing in Higher Education

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--Manuscript Draft--

Manuscript Number:	
Full Title:	Examining the Role of Computing Identity in the Computing Experiences of Women and Racially Minoritized Undergraduates: A Literature Review
Article Type:	Original Research
Keywords:	computing identity; underrepresented minorities; computer science; women; African Americans
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Funding Information:	National Science Foundation (1831964) — Dr. Kinnis Gosha

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Examining the Role of Computing Identity in the Computing Experiences of Women and Racially Minoritized Undergraduates: A Literature Review

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Abstract

This paper offers a synthesis on computing identity and the experiences of women and minoritized populations in computing and computer science in higher education. Examining computing identity and its role in the computing experiences of minoritized undergraduates can help us better understand ways to engage and support women minoritized individuals in the computing field thus increasing participation and persistence of these groups in computing. In this article, we present a review of research literature on computing identity within the experiences of women and minoritized undergraduate students in computing. The research questions of guiding this work are: (1) What research literature exists about computing identity? and (2) According to existing literature, what are the experiences of women and racially minoritized undergraduates in computing (e.g., persons who identify as Black, Hispanic/Latinx, Indigenous people)?, and (3) What theoretical frameworks are used to guide existing computing identity literature? Emergent themes include the need to focus on exposure to computing, persistence, and career expectations, and engagement. While there is no consensus on a computer identity framework, there is research guided by social cognitive career theory. social identity theory, and practice theory. We conclude that computing identity, including its multiple conceptualizations, offers multiple opportunities for informing and broadening participation of minoritized populations in computing. Future research should include further conceptual exploration of computing identity.

Keywords: computing identity, underrepresented minorities, computer science, women, African Americans

Introduction

There is a significant lack of racial and gender representation in computing and computer science (Rodriguez & Lehman, 2017). As a result, the needs and contributions of minoritized populations may not be reflected in computing designs and decisions. A lack of diverse stakeholders who provide input into the functions and design of products can contribute to situations in which products do not meet the needs of society; for example, the development of facial recognition software does not always recognize non-white faces (Bachinni & Lorusso, 2019). Likewise, early voice recognition software designed by males only recognized male voices (Margolis & Fischer, 2002). In addition, a lack of adequate diverse representation in computing can hinder participation of underrepresented groups in computing (Holloman et al, 2021).

Computing identity is an important factor in the matriculation and graduation of undergraduates in computing, and one that especially shapes the experiences of minoritized populations in computing including women and racially minoritized students to include African Americans, Latinx/Hispanics, and indigenous people (Kinnunen et al, 2018; Mahadeo, 2020; Rodriguez & Lehman, 2017). Thus, we propose to examine computing identity and its role in the computing experiences of minoritized undergraduates in computing. In doing so, we can begin to understand ways to engage and support minoritized individuals in computing. In this paper, we examine and synthesize the research literature on computing identity and the experiences of women and racially minoritized undergraduates in computing. The research questions of guiding this work are: (1) What research literature exists about computing identity?, (2) What are the experiences of women and racially minoritized undergraduates in computing (e.g., persons who identify as Black, Hispanic/Latinx, and/or Indigenous) according to existing literature?, and (3) What theoretical frameworks are used to guide the existing computing identity literature?

In the following sections, we provide details about the landscape of existing computing identity in the current literature. There are multiple types of identities discussed in literature related to STEM fields, such as science identity or engineering identity (Dou et al, 2019; Morlock, 2017). However, there are minimal details about computing identity in existing research literature. In this article we first define computing identity,, and then we identify and examine existing research focused on computing identity. Next, we provide details about the

experiences of women and racially minoritized students in computing. Finally, we present a discussion about the implications of the emergent themes from the results and provide some conclusive thoughts and recommendations.

Computing Identity: History and Types of Computing Identity

The term computing identity is fairly new. It was first used in 2001 in a study that examined a young woman's scientific identity formation (Brickhouse & Potter, 2001). Like other identities (science, math, gender etc.), computing identity is thought to be both a career or academic dimension of one's identity referring to how one identifies in the sense that computing aligns with their interests and skills so strongly that it is a part of who they consider themselves to be (see Zahedi et al., 2021). Computing identity is also considered a dimension that is negotiated and renegotiated within a social context (Rodriguez & Lehman, 2017), in this case, a field populated by white men and Asians (Margolis et al, 2017). This means that even if an individual identifies, this identification could be contested or affirmed by credible others in the field. Even though many children participate in STEM activities, many of them do not embrace STEM identities. Archer et al (2010) reported a decline in children's science interest between the ages of 10 and 14, due to being perceived as not exciting enough for boys, and too masculine for girls. Though computer science is a STEM field, research has shown that students tend to classify computing as its own separate category rather than as seeing their pursuit as a general STEM field. More generally, there are ongoing discussions about how computer science should be categorized as it is a multifaceted field and not limited to certain aspects like programming (Denner et al, 1989).

Identity is different than self-efficacy. Students may have a strong sense of STEM efficacy, but that does not necessarily mean they have a strong sense of self-efficacy about computer science (Dempsey et al, 2015). Likewise, an individual's self-efficacy can facilitate interest in the computing field because individuals tend to like activities that they also feel competency within (Dahlberg et al, 2010). There are multiple ways in which computing identity has been defined. Computing identity has been defined as having "a sense of pride and belonging to the community of researchers and practitioners in computer science and information technology" (Boyer et al, 2010, p. 168). Identity is sometimes defined as well as one's sense of belonging in the field (Blunt & Pearson, 2021). Identity can be influenced by stereotypes in the field; for example, members of the computing field are sometimes depicted as persons who neglect their image and appearance, or not perceived to subscribe to acceptable fashion norms (DiSalvo et al, 2011), or a field personified by males or Asians (Abbiss, 2011 & Dempsey et al, 2015).

Theoretical Framing

To review what we learned from the literature on computing, we provide background on three theoretical lenses: social cognitive career theory, social identity, and practice theory. These lenses each provide insight into computing identity from a psychological or sociological perspective. This is important because the theoretical framework changes the particular nature of computing identity, how it is viewed, and how it is studied.

Social Cognitive Career Theory

One primary lens to view Social Cognitive Career Theory as a lens to identify literature that examines the computing identities and experiences of women and racially minoritized populations in computing. Social Cognitive Career Theory (SCCT) says that a person's career choices are based on self-efficacy and outcome expectations. Self-efficacy is belief in one's ability; whereas outcome expectations include concepts like, material gain, social approval and self-satisfaction (Lent et al, 1994). Self-efficacy is indeed a source of outcome behaviors (Lent et al, 2011). However, it is not a measure of skill, but rather a measure of what people believe they can do under varied circumstances (Bandura, 1986). Self-efficacy has to be considered within the context of environmental factors like barriers, support, exposure, etc. (Lent et al, 2011). Thus, self-efficacy can influence people's experiences in various contexts as well as impact their career choices and outcome expectations. According to SCCT, self-efficacy can predict social cognition and identity. Social cognition is defined as the agentic way people construct and direct their lives and experiences. It can be a predictor for future behavior like career choice (Kaminsky & Behrend, 2015). Identity can be thought of as what a person is as well as what they are not. It is multifaceted and lives at the intersection of race, gender and other social constructs (Archer et al, 2010). Therefore, within the SCCT context students either see themselves as computing "people" or not. This can be predicted by self-efficacy because within this framework, one's self-efficacy is so central in how one defines oneself overall. Subsequently, the

majority of articles examined in this review focus on SCCT as the model predicts career or academic identity in computing.

Several concepts like sense of belonging and self-efficacy, have been used to understand students' perceptions and experiences, especially in computing (Santolucito, 2020; Nelson et al 2019; Mahadeo et al, 2020; Wong, 2017). One concept used to examine students' experiences is sense of belonging. Sense of belonging is a person's feeling accepted and integrated into a community (Hausmann et al, 2007). Computing is often perceived as being inaccessible, and some students feel a lack of belonging in computing (Kinnunen et al. 2016). Some students who view computing as inaccessible conceptually have lower interest in the subject or careers linked to it like engineering (Shoaib et al, 2019). Women and certain racial groups have received negative social input that discourages their group (for e.g., women) from pursuing computing (Lent et al, 2011). Carpi et al demonstrated that self-efficacy and persistence in STEM fields can be increased by activities like undergraduate research through incorporating faculty mentoring and other social components such as peer mentoring (2016). In addition, the self-efficacy and persistence of minoritized groups in computing may be adversely impacted given the lack of role models in a field that is dominated by white men and Asians (Margolis et al, 2017). Therefore, these groups may have lower self-efficacy expectation outcomes if they perceive that only certain groups (themselves excluded) excel in the field. Research also shows that mentoring and role-modeling influence self-efficacy and career interest in underrepresented groups in STEM (Barnir, 2011; Carpi et al 2016; Lent et al 2011). This work highlights factors that influence self-efficacy as well as outcome expectations as related to computing careers, and how two correlate to computing identity of minoritized students.

Social Identity Theory and Stereotype Threat

Social identity theory posits that individuals develop some of their identity, or the ways in which they define or categorize themselves, from their membership in social groups (Jenkins, 2014). Social identities may include race, gender, age, religion, or sexual orientation, among other social identities. Prior to this, identity was considered focused more particularly on roles people inhabit based on family or occupation (e.g., mother, brother, engineer, teacher). Social group membership comes with certain contingencies and expectations, with implications for human behavior (Hoggs et al, 2003; Ellemers et al, 1999). Contingencies can be thought of as consequences or social rules according to one's membership; there were times where only white people could use the swimming pools while African Americans were excluded, or where only white men could attend universities, and women across races were excluded. This admission or exclusion would be considered a contingency based on race or gender.

Stereotypes also play an important role because they provide information that can support or impede participation in certain activities or performance within those activities. In some cases, people will underperform within an activity important to them when facing the prospect that poor performance will confirm a negative stereotype. Researchers refer to this stress of trying to avoid fulfilling a negative stereotype "stereotype threat" (Steele & Aronson, 1995). Stereotypes can affect the behavior of any group, even those not typically minoritized in a domain, but for whom a negative stereotype exists and is relevant. For example, even white men underperform when taking a high-stakes math test (Aronson et al., 1999) or when completing athletic activities (Stone et al., 1999). Beyond stereotype threat, there is evidence that social identity can be threatened by particular cues in one's environment, including the overrepresentation of white and male persons, and such information can deter participation in that activity, especially if they are minoritized due to gender or race. The impact of stereotypes or stereotypical cues on social identity is one of diminished sense of belonging; people may come away feeling "I'm not a math person" (Good et al., 2012) or "I'm not a computing person" (Cheryan et al., 2009), and choose to put their efforts elsewhere. In other words, as an individual engages in computing and begins to develop a computing identity, they may have to contend with stereotypes in the field or the fact that they are minoritized. This may in fact preclude engagement before a learner has even considered enrolling in a course, or may deter further enrollment despite excelling. While social identity theory is also psychological in nature, the focus is different than SCCT, which emphasizes self-efficacy and mastery experiences. While SCCT clearly acknowledges the role of teachers and mentors, particularly in providing feedback and access to field-relevant experiences, - and it is different from practice theory.

Practice Theory

While SCCT and social identity theory, both rooted in psychological perspectives, are the most common perspectives guiding work on computer science identity, there are additional perspectives. For example, computer science identity is also guided by practice theory which is rooted within sociological perspectives. Within practice theory, learning to become a (computer) scientist involves engaging with others in the field as apprentices learning the trades of experts. As individuals gain more experience and interact with others in the community of practice (whether a course, research team, workplace setting), they begin to take on the identity of a (computer) scientist (see Lave and Wenger, 1991). As Carlone and Johnson (2007) explained in their work, this identity negotiation process is more complex for individuals minoritized in the field, including women of color, as it is not just about their competence in the domain (e.g., being able to debug a difficult coding problem) or their effective performance of the key activities (e.g., presenting at a conference); beyond this, those credible in the field need to recognize a newcomer's efforts as legitimate. This perspective centers the power dynamics that shape identity within a sociocultural context. Given the historical legacy of exclusion of women and racially minoritized individuals in computer science, one can certainly envision many situations where a woman of color is behaving as a computer scientist and even sees herself as one, and yet is not recognized by professors, peers, or work supervisors as doing so. This makes computer science identity something that one cannot claim on their own but rather something that is negotiated with credible others within complex power structures. Also, identity is thought to be constructed and negotiated within social contexts. For example, gender, is defined relative to societal norms, and within discourses (Gee, 2000).

With these three theoretical lenses in mind, we undertook our study of the research literature to assess the themes of findings pertinent to computer science identity with a focus on undergraduates who are minoritized, whether by gender and/or race. Beyond this, we considered important areas for future work whether theoretically or methodologically in this area. Finally, we also considered recommendations for practice.

Methods

Overview

In this literature review, we examine current literature on computing identity. We employed several methods to search, collect, and analyze existing literature about computer science, searching across three databases with several search terms. We included articles in our review based on whether computing identity (e.g., relating to the identity of someone who participates in computing) was a theme of the article. Then, we summarized included articles in a running annotated bibliography, which we then synthesized. The questions guiding this work are: (1) what literature exists about computing identity?, (2) what are the experiences of women and racially minoritized undergraduates in computing (e.g., women and/or persons who identify as Black, Hispanic/Latinx, American Indian/Alaska Native) according to existing literature?, and (3) what theoretical frameworks are used to guide the existing computing identity literature?

Methods Planning

Three databases were used: Scopus, for its breadth, the Association for Computing Machinery Digital Library (ACM DL), for its relevance to computing topics, and the Education Resources Information Center (ERIC), for its relevance to undergraduate education.

Inclusion Criteria

Because computing identity is a relatively newly examined construct, we included any article that mentioned "computing identity" or "computer science identity" in the title or abstract, in the context of how people identify in the field of computing or their sense of belonging in computing. We excluded articles that turned out to be focused on computer security rather than people pursuing computer science or computing. We also restricted the search to articles that focused on college students and/or undergraduates.

Searches

We searched the three databases using searches which are summarized below in Table 1. Different searches were used for different databases because the databases had different foci. For example, ACM focuses on Computer Science topics, so specification of computing was not always needed for an effective search. Searches include papers through 2021. Additionally, the authors included papers identified from citations of included papers, as well as from prior knowledge of the field. We found 34 articles, as well as over 100 others that did not meet inclusion criteria but were intended to inform the research (e.g., they pertained to science identity or computer science efficacy or persistence among undergraduates).

Table 1. Keyword Searches across Databases

	Scopus	ACM DL	ERIC
Computing Identity	X	X	X
Computing Belonging			X
Undergraduate Identity		X	

Results

There were 34 articles that met the study's inclusion criteria, refer to Table 2. Of those 34 articles, 10 focused solely on women in computing, and 6 related to only racially minoritized groups in computing. Seven articles related to both women and racially minoritized groups, and the remaining 11 addressed high school or college students, but not women or minoritized groups. We identified four main themes across all of the articles, with some articles pertaining to multiple themes. Specifically, the research literature indicates that there are several challenges and opportunities related to computing identity and women and minoritized populations. In the following paragraphs, we discuss both the broader landscape of computing identity, as well computing identity in relation to minoritized populations. First, several articles discussed development of computing identity and potential frameworks. Another emergent theme of the articles involves recognizing a need to better engage underrepresented groups such as women and minoritized populations in computing. The third emergent theme focuses on the importance of exposure to computing, persistence, and career expectations. In the following paragraphs, we discuss specific details about the articles that correspond to these themes and the proposed research questions.

Table 2. Summary of Articles

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M.	2009	*Journal of Personality and Social Psychology*	Ambient belonging: how stereotypical cues impact gender participation in computer science	Quantitative	175 college students	Women	Sense of belonging: Ambient belonging (Astin, 1993)	3 different studies to investigate the effect of male artifacts in computing spaces on women's sense of belonging	Male artifacts like star trek posters in computing spaces can discourage women from participating in computing even in all female cohorts.
Bell-Watkins, K., Barnes, T., & Thomas, N.	2009	*Journal of Computing Sciences in Colleges*	*Developing computing identity as a model for prioritizing dynamic K-12 computing curricular standards*	Framework Development	N/A	No	None	Uses Students and Technology in Academia, Research, and Service (STARS) and Thomas principles for mentoring success to develop a computing identity framework	Propose Computing Identity Framework Model that can be used for the SPE (Standards Prioritization Engine) for developing and prioritizing K-12 computing standard
Zander, C., Boustedt, J., McCartney, R., Moström, J. E., Sanders, K., & Thomas, L.	2009	*ICER '09*	*Student transformations: Are they computer scientists yet?*	Qualitative	108 computing majors in the second half of their degree programs from the USA, UK, and Sweden	No	Social Constructivism (Lave & Wenger, 1991) Ways of thinking and processing (McCune & Hounsell, 2005)	Students were asked to identify a computing concept that transformed the way they saw computing and describe that transformation, and then the researchers performed qualitative content analysis.	Four major categories of computer science identity: professional computer scientist or software developer, CS as a tool that has applications, and CS as an intellectual discipline. Level of CS identity varied widely, with some identifying more as students, but those further along identifying with the broader community, and this can be fueled by learning certain concepts.
Boyer, K. E., Thomas, E. N., Rorrer, A. S., Cooper, D., & Vouk, M. A.	2010	SIGCSE '10	*Increasing technical excellence, leadership and commitment of computing students through identity-based mentoring*	Quantitative	84 students from seven institutions in the STARS Alliance, who had participated in the Computing Identity Mentoring program or another mentoring program.	No	Identity-based mentoring (Dahlberg et al, 2005; Thoms, 2005)	Sent out pre- and post-surveys of both Computing Identity Mentoring students and students who had participated in other mentoring programs at seven institutions across the STARS Alliance	Participating in a mentorship program was beneficial for the students' computing identity in developing their confidence, technical skills and knowledge, and committing to a career in computing and knowing they'll get a job they like

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Dahlberg, T., Barnes, T., Buch, K., Bean, K.	2010	*Computer Science Education*	*Applying service learning to computer science: Attracting and engaging under-represented students*	Quantitative	37 university students in a Leadership Seminar at the Computing College	Women, African American, Hispanic	Service Learning (Astin, 2000)	Measured self-efficacy with Longitudinal Assessment of Engineering Self-Efficacy and replaced engineering with computing, A subscale consisting of three computing-specific self-efficacy items was created from these items. Similarly, three identity items from LAESE were adapted to create a ''computing identity'' subscale. The authors also developed a questionnaire to measure leadership/team skills.	Students in the program had a high sense of computing efficacy and identity, and there was a significant difference between them and the control for identity, but not efficacy. This is partially due to the opportunity to work with faculty, peers, and people who look like them. Student involvement in service learning may affect computing identity more than it affects computing efficacy.
James DiSalvo, B., Yardi, S., Guzdial, M., McKlin, T., Meadows, C., Perry, K., & Bruckman, A.	2011	*CHI '11*	*African American males constructing computing identity*	Mixed Methods	23 male African American high school Glitch program participants	African Americans	Disidentification (Eglash, 2004)	Pre and post tests and surveys were administered and the Wilcoxon rank-sum test was done to analyze comparisons. Interview and focus groups were also conducted to gather qualitative data on participant experiences	Social structures and their influence on computing identities must be considered. Newcomers benefit from having the social support in communities of practice in order to build interest. Computing contextualized as a career and the social status it holds also helps, and contributes to building an identity
Abbiss, J	2011	*Gender and Education*	*Boys and Machines: Gendered Computer Identities, Regulation and Resistance*	Qualitative	Three separate IT classes at Kahikatea High School in New Zealand	Women	Social Constructivist post positivist feminist in ICT (Gilbert, 2001; Butler, 2001)	Collected audio records of classroom conversations, notes from lesson observations, and interviews with teachers and with student pairs. To analyze the data, constructed descriptions of individual students' experiences of specialist IT courses, and also analyzed field texts thematically.	Students hold strongly held gendered perceptions of computer use, and sort uses into three categories: expert, aspiring, and competent, with girls generally identifying as competent.
Peters, A. K., & Pears, A.	2013	*LaTiCE '13.*	*Engagement in computer science and IT - What! A matter of identity?*	Qualitative	149 novice students of the Computer Science and IT engineering programme at Uppsala University	No	Social theory of learning/ Community of practice/student epistemological development (Lave & Wenger, 1991)	Collected reflections in which the students reflect on their choice of study program, goals, and expectations for education. Performed thematic analysis, iterative coding, and explorative deductive analysis on the reflections.	There are two primary groups within the students: those focusing on computers/applications, and those focusing on technology in society, and are very different from where they derive their meaning for computing; higher education is more significant for the second group, as they are looking for more than just skill, which is the primary focus of the first group.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Peters, A. K., & Rick, D.	2014	WiPSCE '14	Identity development in computing education: theoretical perspectives and an implementation in the classroom	Framework Development	17-year-old students enrolled in a Computer Science in Germany	No	Identity/Bildung (self-development/world disclosure) (von humboldt, 2000; Situated Learning Lave & Wenger, 1991)	Integrate a psychosocial and a sociocultural perspective on identity development, and then perform example project work in a school	The theoretical framework can help understand parts of learning beyond knowledge acquisition and design situated learning environments and experiences that foster identification processes and participation in group activities
Denner, J., Lyon, L. A., & Werner, L.	2015	*GenderIT '15*	*Does Gender Matter? Women Talk about Being Female in College Computing Classes*	Qualitative	70 women taking an introductory computer science class at either a university or community college	Women	Identity (Settles, 2004)	Data from online posts and interviews were collected and organized into major themes.	Being female fell into one of three categories in relation to CS: irrelevant, motivational, or incompatible, with irrelevant being the primary category. Thus, a gender focus may no longer effectively increase female persistence in CS.
Wong, B	2016	*Computer Science Education*	*I'm good, but not that good': digitally-skilled young people's identity in computing*	Qualitative	32 teenagers enrolled in a fully funded computing summer school in Britain	No	Identity (Butler, 1990)	Semi-structured interviews were transcribed and coded iteratively, then analysed through identity discourses of computing.	There is a mismatch between the computing identities of the digitally skilled youth and the assumed identities of computing professionals
Castro, B., Diaz, T., Gee, M., Justice, R., Kwan, D., Seshadri, P., & Dodds, Z.	2016	SIGCSE '16	MyCS at 5: Assessing a Middle-years CS Curriculum	Quantitative	3973 US grades 4-10 students both enrolled or not enrolled in MyCS courses	Women, Black/African American, Latina/o, Native American, Multiracial	None	Three times in 2014-15, in Sep., Dec., and May, partnering teachers asked their students to complete a nine-question survey elaborating computational identity, which was measured on a Likert scale, and differences were analyzed	MyCS does not bolster students' positive computational identities more than the control, but it does offer a home for engaging those students – from a representative cross-section of the surrounding district – who identify significantly more positively with computing, as well as leading to a deeper institutional identification with computing
Rodriguez, S. L., & Lehman, K.	2017	*Computer Science Education*	*Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory*	Literature review	Various populations from different sources of literature to explore, define, and contextualize computing identity	Women; URMs	Identity development/ sense of belonging (Chervan, 2009; Goldston & Kyzer, 2009; Holland & Lave, 2001)	Cites other literature to explore and flesh out the definition of computing identity, then lists practical ways it could be applied.	An intersectional computing identity definition that takes into account women and URM is necessary to allow for intersecting personalities and to inform research and practice

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Dubow, W., Kaminsky, A., Weidler-Lewis, J.	2017	*Computing in Science & Engineering*	*Multiple Factors Converge to Influence Women's Persistence in Computing: A Qualitative Analysis*	Qualitative	64 women (winners and nominees of the NCWIT Award for Aspirations in Computing (AiC))	Women	Sense of belonging (L.J. Barker et al., 2006)	In-depth interviews held either individually or within a focus group. Applied both content-based codes as well as codes that were emergent constructs in the data.	Multiple supportive factors that contribute to women intending to pursue, or actually pursuing, computing include having sufficient exposure to learn computing skills, whether in school or out of school; sufficient community support, including teachers, parents, and peers; and respect and encouragement from other individuals in their computing journey.
Kinnunen, P., Butler, M., Morgan, M., Nylen, A., Peters, A. K., Sinclair, J., & Pesonen, E.	2018	*European Journal of Engineering Education*	*Understanding Initial Undergraduate Expectations and Identity in Computing Studies*	Qualitative	First year CS students in Finland, Sweden, and the UK	No	Expectation (Brattesani, 1984)	Students filled out surveys at the beginning of their studies answering five open-ended questions. A collaborative inductive content analysis was used to create meta- and sub-categories.	Supporting students to develop identity within CS requires presenting different engagement modes students can negotiate their identity with. Additionally, shifting the perception of CS away from only programming to its larger societal role might help recruit more diverse students.
Garcia, A., Ross, M., Hazari, Z., Weiss, M., Christensen, K., & Georgiopoulos, M.	2018	*Collaborative Network for Engineering and Computing Diversity (CoNECD)*	*Examining the Computing Identity of High-Achieving Underserved Computing Students on the Basis of Gender, Field, and Year in School*	Quantitative	93 full-time high-achieving underserved students in computing engineering, computer science, and information technology	Women	STEM identity (Goodwin et al., 2016)	Exploratory factor analysis used to assess validity of sub-constructs, and Kruskal-Wallis non-parametric tests to compare groups	Female students had significantly lower recognition sub-construct scores and overall computing identity. IT students also had a significantly lower overall computing identity, as well as first year students, who also were significantly lower in their interest and performance/competence sub-constructs.
Taheri, M., Ross, M., Hazari, Z., Weiss, M., Georgiopoulos, M., Christensen, K., & Chari, D.	2018	*2018 IEEE Frontiers in Education Conference (FIE)*	*A structural equation model analysis of computing identity sub-constructs and student academic persistence*	Quantitative	1640 undergraduate students at three metropolitan public institutions	Women	Identity, STEM identity (Gee, 2000, Tyler, 2014)	A quantitative Flit-Path survey was sent to undergraduate students at three universities in Florida and structural equation modeling (SEM) was used to analyze effects of constructs while confirmatory factor analysis was used to validate the construct measures.	Interest had the strongest direct effect on persistence, while beliefs of self-competence were also significant. Recognition was indirectly and directly effective on persistence through interest. Sense of belonging directly affected competence and performance.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Hampton, L., Cummings, R., & Gosha, K.	2019	*SIGMIS-CPR '19*	*Improving computer science instruction and computer use for African American secondary school students: A focus group exploration of computer science identity of African American teachers*	Qualitative	4 African American secondary school STEM teachers in the Metro Atlanta, GA region	African Americans	Sense of Belonging (Walton & Chen, 2007) Self-efficacy (Bandura, 1997)	Used a qualitative focus group. Computing identity was measured as a combination of sense of belonging and self-efficacy, not as a construct of its own, and equivalent to CS identity.	Teachers lack resources and paid training time to teach CS. Some students are burned out by the CS courses that are taught.
Kapoor, A., & Gardner-McCune, C.	2019	Proceedings of 24th Annual ACM Conference on Innovation and Technology in Computer Science Education	Understanding CS Undergraduate Students' Professional Identity through the lens of their Professional Development	Mixed Methods	14 CS/CE undergraduate students	No	Identity status theory (Marci, 1966) SCCT (Lent et al, 2004)	A cross-sectional mixed-method study using a Concurrent Triangulation Design. Recruited a mix of interview participants equally representing gender and academic standing from our survey participants to gather information-rich cases through purposeful sampling, triangulated the data to ensure reliability, before collecting data from multiple institutions on developing a computing professional identity theory.	Found two groups of students, moratorium, who were uncommitted to a specific profession, and achieved, who had committed to a specific profession. This professional identity typically forms in the second or third year.
Pantic, K., & Clarke-Midura, J.	2019	*Journal of Women and Minorities in Science and Engineering*	*Factors that influence retention of women in the computer science major: a systematic literature review*	Systematic Literature Review	Undergraduate women in CS majors	Women	Tinto's model of institutional departure (Tinto, 1993; Falcone, 2011; Giuffreda, 2006)	Keywords 'women', 'computer science', and 'retention' used within ERIC, Education Source, Google Scholar, and ACM Digital Library to find 102 titles for analysis. These studies were included if they addressed the issue of retention of undergraduate women in CS majors (not STEM overall).	Individual - many studies show differences between male and female pre-entry attributes, including less computer and programming experience, less confidence and resource use, and different intellectual and social preferences (e.g. gaming). Redesigned CS courses can help with this, such as contextualized programming for the real world, in addition to same-sex project groups or learning communities Institutional - initial interactions with those in their program must be positive for reinforced persistence, especially with attentive faculty and peers. Female faculty and peer role models and changing departmental culture help with this Societal - concerns of future family-work balance was a large factor, as well as social support from peers, family support, and cultural norms in other countries

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Taheri, M.,	2019	*American Society for Engineering Education, 2019*	*Exploring computing identity and persistence across multiple groups using structural equation modeling*	Quantitative	1640 students in IT, CS, and CE at 3 public Florida universities.	Women	SCCT (Lent et al., 1994, Lent & Brown, 2002)	Quantitative, 22 item survey. Used structural equation model analysis to see how identity sub-constructs contributed to persistence in computing by first performing a confirmatory factor analysis to ensure valid measurements from the model. Then used invariance measurement testing to compare male and female, freshman and senior students and Chi-square difference test to see if comparison was significant.	All sub-constructs (recognition, interest, sense of belonging, and competence/performance) have some impact on persistence in computing, with interest being the most significant direct impact. There are indications that students feeling recognized or like they belong can help towards becoming interested and feeling competent in performing, respectively, which both directly impact persistence.
Lehman, K.J.	2019	*2019 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*	*An Untapped Recruitment Pool: Undecided Students in CS1 Courses*	Mixed methods	Quantitative data from the Building, Recruiting, and Inclusion for Diversity (BRAID) research project, and interviews were taken from students in introductory computing courses	Women, Black/ African American people, Hispanic/ Latino/a people	Science identity (Carlone & Johnson, 2007)	Drawing from Carlone and Johnson's science identity theory, applied to undecided students in the computing sciences, students in introductory computing courses were interviewed about their experiences in computing.	Undecided students may serve as a good pool from which to recruit women but are not a diverse group in terms of race/ethnicity. It is possible that students from historically underrepresented groups tend to make a commitment to a college major sooner than White and Asian students do, which could explain their lower presence in undecided majors.
Nelson, W., Cummings, R.T., Gosha, K.	2020	*2019 IEEE Frontiers in Education Conference (FIE)*	*A Qualitative Investigation on the Effectiveness of a Computing Identity Development Emailing List for African American Computer Scientists*	Mixed methods	21 members of the African American PhDs in Computer Science (AAPHDCS) listserv	African Americans	Resilience (McGee, 2016)	Survey with 26-item User Experience Questionnaire (UEQ). Semi-structured interviews were conducted to see how effective the listserv was in maintaining participants' resilience in their computing identity.	Computing identity in African American students can be maintained by building a sense of belonging within a community, inspiring optimism, and bolstering feelings of self-efficacy. These can converge to create a model of resilience to possibly help lower attrition rates.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Cummings, R.T. Huff, E.H., Mack, N.A., Womack, K., Reid, A., Ghoram, B., Gosha, K., Gilbert, J.E.	2020	Computing in Science & Engineering	An Exploration of Black Students Interacting with Computing College and Career Readiness Vlog Commentary Social Media Influencers	Mixed Methods	Youtube videos in vlog commentary format, dealing with the graduate school or industry careers in STEM, by an ethnic minority or a woman	Black people	Mentoring (Berk et al., 2005)	First, a synthesis of vlog commentary college and career advisement videos, coding for the quality of advisement, usability, and user experience; second, an advisor effectiveness and user experience survey using a selected Black social media influencer who provides computing college and career advisement; and third, a user experience and interaction preference survey using a selected Black social media influencer.	YouTube influencers could be effective in developing computing identity in Black students, particularly for beginners in the computing field
Mahadeo, J., Hazari, Z., & Potvin, G.	2020	*ACM Transactions on Computing Education*	*Developing a computing identity framework: Understanding computer science and information technology career choice*	Quantitative	1704 students in an introductory physics course at 22 US colleges	Black (African American) people; Hispanic people; Women (Female)	Identity theory (Hazari et al., 2010) Self-efficacy (Bandura, 1999)	Administered a survey to students; nine items in the survey were mapped to the sub-constructs in a computing identity model, and multilevel confirmatory factor analysis was used to evaluate.	All three sub-constructs were significantly positive predictors of students' career choice in CS and IT: interest, performance/competence, and recognition, in order of strength of prediction. There were no significant differences by race, but males have a significantly higher computing identity than female students.
Santolucito, M, Piskac, V	2020	*SIGCSE '20*	*Formal methods and computing identity-based mentorship for early stage researchers*	Qualitative	Four high school and five undergraduate students involved in the lab group's research	No	Identity-based mentoring (Boyer et al., 2010)	Case study of four high school students and five undergraduates who participated in formal methods research in their lab group.	It is important to involve students before their final year of undergrad to increase long term collaboration quality, although this can be difficult, especially when it comes to undergrads. To best encourage computing identity, projects should be non-critical but still contribute significantly. Giving high school and college students research tasks perceived as both difficult and important along with mentoring helps increase computing identity.
Bettin, B., Jarvie-Eggart, M., Steelman, K. S., & Wallace, C.t	2020	2020 IEEE Frontiers in Education Conference (FIE)	Infusing Computing Identity into Introductory Engineering Instruction	Mixed Methods	Master class of ENG1 Students	No	Identity Based Mentoring (Boyer et al., 2010)	Student reflections from engineering course	Work in progress

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Lundberg, G. M., & Ness, I. J.	2020	9th Computer Science Education Research Conference	First year students' imagination of future employment: identity as an important employability aspect	Qualitative	Eight first-year students in a three year program on cybersecurity and infrastructure in the Netherlands	No	Situated learning (Lave & Wenger, 1991)	Semi-structured interviews, recorded, transcribed, and analyzed intuitively	Many students did not know what their dream job was, but imagination could be an important tool in helping them think about it.
Blunt, P.; Pearson, T	2021	SIGCSE '21	Exploring the Digital Identity Divide: A Call for Attention to Computing Identity at HBCUs	Call for Intervention?	First year CS students at HBCUs	Black people	Computing Identity (Dempsey et al, 2015) Situated Learning (Lave & Wenger, 1991)	Position paper	Propose course on The Afro Diasporic Narratives of Computing Identity
Zahedi, L., Batten, J., Ross, M., Potvin, G., Damas, S., Clarke, P., & Davis, D.	2021	*Journal of Computing in Higher Education*	*Gamification in education: a mixed-methods study of gender on computer science students' academic performance and identity development*	Mixed Methods	181 undergraduate CS students	Women	Social Identity theory (Pugh, 2010) Self-efficacy (Bandura, 1977	Used SEP-CyLE: online gamified tool to measure its effects on women in CS's identity development, self-efficacy, and experiences	Gamification is useful for improving performance of both genders. Females perceived SEP-CyLE (Software Engineering and Programming Cyberlearning Environment) more negatively than males, but the intro computer programming class did help female students with understanding their computing identity
Widdicks, K., Ashcroft, A., Winter, E., & Blair, L.	2021	*United Kingdom and Ireland Computing Education Research conference*	Women's Sense of Belonging in Computer Science Education: The Need for a Collective Response	Qualitative	13 undergraduates and postgraduates	Women	Sense of belonging (Cheryan et al., 2009)	Understanding how women perceive sense of belonging	Women shared experiences of not belonging as well as belonging; discussing measures like role models, and identity celebration to encourage belonging
Holloman, T., London, J., Lee, W. C., Pee, C. M., Ash, C. H., & Watford, B.	2021	*IJEE International Journal of Engineering Education*	Underrepresented and Overlooked: Insights from a Systematic Literature Review about Black Graduate Students in Engineering and Computer Science	Quantitative	Literature review	African American graduate students	None	Systematic literature review	Factors impacting students pursuing computing in grad school: student identity, recruiting and persistence and grad school perception

Research Question #1: What research literature exists about computing identity?

Overall, we found a total of 35 articles relating to computing identity, indicating that the concept as a whole is still underdeveloped, particularly in comparison with similar concepts, such as science identity, which are much more established. Much of the literature is recent, as displayed in Figure 1, indicating a growing interest in the field. There were three main themes that emerged about computing identities related to defining computing identity, the role of engagement in computing, the necessity for role models with similar identities, and the importance of exposure to persistence in computing identity. In the following paragraphs, we summarize the articles related to each of these themes.

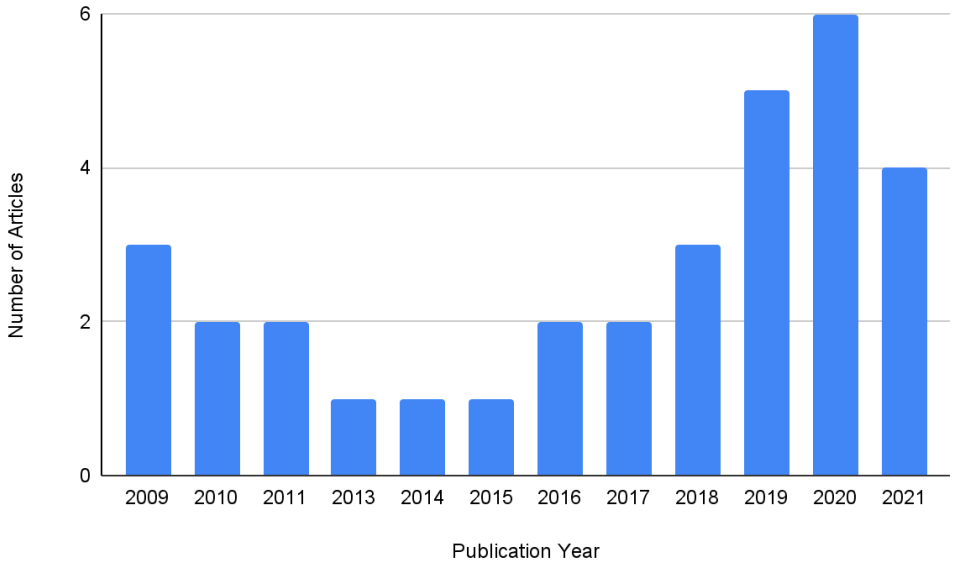

Figure 1. Number of Articles by Publication Year

Lack of a consensus about computing identity. Notably, unlike science identity, there is no commonly accepted computing identity definition or framework. Three of the articles focused on developing frameworks related to computing identity. Bell-Watkins et al (2009) focused on a curriculum development framework, which discusses developing standards for K-12 computing education Similarly, Peters & Rick (2014) developed a framework which involved leveraging identity development-inner/outer self using a traditional German pedagogical philosophy, and situated learning. In contrast, building off of Carlone and Johnson's (2007) science identity work, Mahadeo et al, 2020 created a computing identity framework based on interest, performance/competence, and recognition. This work was also the only one to validate the framework with quantitative analysis, and it was found to be reliable. However, given its preliminary status, it is unclear if others will adopt it in further work (2020).

The Role of Engagement and the Necessity of Role Models. The importance of engagement involving minoritized populations and women was the focus of 23 articles. First, several articles discussed the importance of practical hands-on computer science engagement beyond programming language and more abstract theory (Zander et al, 2009, Dahlberg et al, 2010, Kapoor & McCune, 2019). In addition, several papers reported factors about minoritized engagement in computer science. For example, 7 papers discussed the need for students to work on meaningful projects where they assume roles, which encouraged them to perceive themselves as computer scientists. In addition, almost a third of the articles discussed the need for minoritized populations to have role models with similar identities in CS (Rodriguez & Lehman, 2017; Nelson et al, 2020; Cummings et al, 2019; Holloman et al, 2021). Similar to minoritized engagement, female participation was also discussed in several studies. Again, there is a need for role models, as well as increased awareness of discrimination towards women in computing courses (Cheryan et al, 2009; Denner et al, 2015; Abbiss, 2011; Blaney & Stout, 2017: Dubow et al, 2017; Garcia et al, 2018; Pantic & Clarke-Midura, 2019; Taheri et al, 2019; Lehman, 2019; Zahedi et al, 2021; Widdicks et al, 2021).

The Role of Exposure, Persistence, and Expectations. Fifteen articles examined early exposure (pre-college and early college), persistence, social influence and expectations in computing. Early exposure to CS begins the process of helping students see themselves as belonging in the computing world (Bell-Watkins et al., 2009; Peters & Rick, 2014; Castro et al, 2016; Dubow et al, 2017; Hampton et al, 2019; Santolucito & Piskac, 2020; Bettin et al, 2020; Lundberg & Ness, 2020). Other articles reported how having friends (DiSalvo et al, 2011), family (Dubow et al, 2017), and community (DiSalvo et al, 2011) who are interested in CS can help to support students' development of computing identity. For example, if a students' friends are not interested or also engaged in computing could derail their interest. Likewise, if students' families or schools do not encourage participation in computing, this can also be a hindrance to their interest in computing (DiSalvo et al, 2011; Dubow et al, 2017; Taheri et al; Hampton et al, 2019; Blunt & Pearson, 2021). Finally, other researchers indicated the need to broaden the scope of careers in computing. Specifically, students should see that computing has many applications in different fields (e.g., accounting) (Peters and Pears, 2013; Kinnunen et al, 2018; Bettin et al, 2020; Lundberg & Ness, 2020).

Research Question #2: What are the experiences of women and racially minoritized undergraduates in computing (e.g., persons who identify as Black, Hispanic/Latinx, and/or Indigenous) literature?

Experiences of women: A need for intersectional identity recognition/gender of focus. Of the 34 articles, 11 focused on women. Of the 13 articles focusing on minoritized populations, approximately 50% also focused on women (Dahlberg et al, 2010; Lehman 2019; Sax et al, 2018; Castro et al 2016; Rodriguez and Lehman 2017). There were differing themes among articles, some emphasizing the need for more work in developing the computing identities of women, such as Rodriguez and Lehman, who in their 2017 paper argue for the need for the computing field to not consider computing identity alone, but intersectional computing identity, in order to recruit more women and underrepresented minorities. On the other hand, this was not a universally supported argument, with Denner et al arguing that a gender focus may not actually be a useful method to increase female participation in CS (2015). The concept of ambient belonging in computing was also investigated by Cheryan et al. Computing fields with objects perceived to be masculine (for e.g., Star Trek posters) can deter women from persisting in the field. In addition to not feeling welcome in the space, women may also feel like they would have to give up their gender identity to be accepted (Cheryan et al, 2009). There is also a necessity to use gender neutral language in classroom settings. This can reduce the incidence of hidden stereotypes, which often biases the computing field towards men (Widdicks et al, 2021).

Experiences of racially minoritized students: aspects that affect computing identity. Six articles focused on minoritized populations. Another seven articles focused on both women and minoritized students. Eleven articles examined the experiences of Black or African American people, 4 had a focus on Hispanic/Latinx populations, 1 focused on multiracial students, and 1 focused on racially minoritized students as a whole. A number of articles discussed the importance of developing computing identity as part of recruiting and retaining racially minoritized students. (DiSalvo et al 2011; Nelson et al 2020; Cummings et al 2020; Dahlberg et al 2010) In particular, Nelson et al 2020 argued for the importance of developing community for African American students to help them develop their computing identities.

Research Question #3: What theoretical frameworks are used to guide existing computing identity literature?

In reviewing the articles, we found that existing computing identity literature uses various theoretical frameworks. Identity was specified as a theoretical framework in 12 articles. Specifically, identity theories inclusive of social identity, STEM identity and computer identity, and identity development, and identity based mentoring. Other frameworks used included sense of belonging (4), situated learning (4), SCCT (2), service learning (1) and mentoring (1), resilience, (1), institutional departure, (1), self-efficacy(4), expectation(1), social theory of learning (1), social constructivism (1), computing identity(1), and disidentification (1). Some articles leveraged more than one framework, and three articles did not use any framework.

Discussion

Our literature review suggests that there are three main themes from this synthesis of the emergent literature. There is the need for an established computing identity framework, which can inform how students elect, engage and persist in the field. Another theme is the importance of early exposure for minoritized populations and women. In addition, the final theme discussed is the need for role models with similar identities, and mentors to help support women and minoritized individuals in computing.

Developing Computing identity as a Model for Persistence

There appears to be no one accepted definition or framework about computing identity. Eight articles outlined computing identity framework development as a necessary foundation to discuss underrepresented groups participation and persistence in computing (Bell-Watkins et al, 2009; Peters & Detlef, 2014; Rodriguez & Lehman, 2017; Taheri et al, 2018; Pantic & Clarke-Midura, 2019; Taheri et al, 2019; Santolucito & Piskac, 2020). As a rapidly growing field, many of the articles focused on computing identity as either a means to explain or increase persistence (Boyer et al 2010; Dahlberg et al 2010; Denner et al 2015; Dubow et al 2017; Stout et al 2017; Kinnunen et al 2018; Tahari et al 2018; Pantic & Clarke-Madura 2019; Taheri et al 2019; Kapoor et al 2019; Nelson et al 2020). Many of these articles specifically considered the persistence of minoritized students in computing. Early engagement, and a multilayered support structure, which includes role models are needed to encourage women and underrepresented minorities to embrace the computing identity. This may help them engage and persist in the field (Dubow, 2017; Pantic & Clarke-Midura, 2019; Santalucito & Piskac, 2020).

The role of identity: A need for models?

Of the 35 articles, 24 of them focused on a population underrepresented within computing, among them 11 with a focus on women specifically and 7 with a focus on both racially minoritized students and women, and 6 focused on African Americans. This indicates that the experience of minoritized students is of interest in the field; yet, only a few of these articles discuss both women and minoritized populations. Computing has historically been associated with white men (Blunt, 2021). Thus, historically underrepresented and minoritized populations are less likely to identify with computing because of the negative stereotypes associated with the field and their exclusion. In fact, there is often disidentification among Black men and women, as computing is seen as something outside of the social norm within their peer groups (DiSalvo et al 2011; Solomon et. al 2018). It can be difficult to recruit members of minoritized groups due to the "white" or "uncool" stigmas associated with computing, and even more difficult to retain students as there is a loss in interest due to low self-efficacy and lack of belonging (Kinnunen et. al 2015). Minoritized students and women frequently lack role models with similar racial or gender identities to engage with in the field, and find themselves navigating masculine white/Asian spaces, which are usually not perceived to be inclusive (Dahlberg et al, 2010; Abbiss, 2011; Margolis et al, 2017; Holloman et al, 2021).

The Importance of Engagement

Studies show that students respond better to computing as a field when they are exposed to practical applications versus just learning theory (Zander et al, 2009; Dahlberg et al, 2010; Kapoor & McCune, 2019). Project-based learning with real-world applications where students assume roles and tasks may present the field in an accessible way. This can help take perception of the field outside the realm of programming language and codes, to hands on applications (Kinnunen et al, 2018). This is especially useful for minoritized populations, where this rich exposure can help them assume the identity as discussed above and pursue careers in the field. What is often useful is if minoritized students have friends alongside them in these activities, as well as parental/teacher and community support (DiSalvo et al, 2011). Therefore, the social aspect of learning (participation and acknowledgment by others) is a necessary component to engage minoritized students (Blunt & Pearson, 2021; Castro et al, 2016; Dahlberg et al, 2010; DiSalvo et al, 2011; Hampton et al, 2019; Nelson et al; Cummings et al, 2020; Rodriguez & Lehman, 2017).

Conclusion

Computing identity and the experiences of minoritized populations in computing remains an under examined field with multiple opportunities to help inform and broaden participation. In this study, we reviewed 34 articles which reported on the experiences of minoritized students and women in the computing field. There were three emergent themes from the literature. These include a need for early exposure and participation in K-12. In addition to this,

meaningful activity (such as app creation), particularly activities in which minoritized students can engage the students with their communities. Another emergent theme is a need for women and minoritized students to see role models with similar identities in computing. Beyond just seeing these role models, but being mentored by these role models can help engage these underrepresented groups. The final theme involves the need for a developed and accepted computing identity framework. This can help guide scholarship and interventions towards increasing access, persistence and completion of women and minoritized students.

Implications for Theoretical and Methodological Development of Computing Identity in Higher Education

Given there are multiple frameworks for conceptualizing computing identity, how we come to understand identity, including threats and how to strengthen identity are also consequences. If identity is considered a property of the individual, we may see more sophisticated survey methods that disentangle computer science identity from programming self-efficacy, computer science classroom identity, or science identity more broadly. For those who conceptualize identity as a negotiation within a social context, we need to better understand the concept of recognition by professors and mentors in the field (Carlone & Johnson, 2007; Hazari et al., 2010). In this frame, those with more credibility and expertise in the field underpin the identity students are currently forming. We may require additional methods, including field notes from lab and class interactions, experience sampling methods for real-time reflections on identity in formation, and greater depth for interview protocol development.

Future Research Recommendations

There are many opportunities for future researchers to help broaden participation through examining perceptions of computer identity and why certain populations perceive computing as they do, mechanisms to help support and increase the computing self-efficacy of women and minoritized populations, and ways to increase the numbers of role models in the field. First, future research should include further exploration and solidification of a computing identity framework. For example, examining why computing identity is perceived to be separate from STEM or science identity. Early engagement, and mentoring does increase interest in computing (Dubow, 2017), but researchers need to investigate how students embrace identity. Understanding computing identity can inform how students can begin to perceive themselves as computer scientists or engineers, as well as possibly change their impression of the field. In addition, minoritized populations and women have viewed the computing field as inaccessible and white male/Asian dominated (Abbiss, 2011).

Implications for Practice

Future educators in higher education should also explore ways to help increase computing self-efficacy in minoritized individuals and women. Early engagement, and mentoring also facilitate female and minoritized interest (Bell-Watkins et al, 2009), yet the numbers of underrepresented minorities and women in the field are dismally low. Harvey Mudd College demonstrated gender parity, after years of disparities, when they created introductory sequences based on prior experience; this disproportionately benefited women who did not have as much prior experience with programming prior to college (Alvarado et al., 2012). Further studies should explore mechanisms that help engage, support, and retain minoritized persons and women in computing higher education. Furthermore, high school and college level intro computing courses can be leveraged to engage students in a meaningful way which broadens their outlook on computers beyond coding and programming. In so doing students can actually see far-reaching applications of computing in different fields and even in their own communities.

Finally, more research is needed to investigate how to effectively attract and groom female and minoritized faculty members in computing higher education spaces. The effect of role-models in garnering interest and participation is a factor with underrepresented populations (Nelson et al, 2020). In addition, studies on how faculty incorporate inclusive pedagogical practices in computing courses could inform computing departments about best-practices for inclusivity which would greatly benefit students. Computing applications have rapidly expanded throughout the 21st century. Intervention programs are in place to increase underrepresented group participation (Castro et al, 2016), but more creative and research informed measures are necessary to move students from interested to active participants in the computing field.

Acknowledgments

[REMOVED FOR REVIEW]

References

Abbiss, J. (2011). Boys and machines: gendered computer identities, regulation and resistance. *Gender and Education*, *23*(5), 601-617.

Alvarado, C., Dodds, Z., & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, *3*, 55–64.

Aronson, J., Lustina, M. J., Good, C., Keough, K., Steele, C. M., & Brown, J. (1999). When White men can't do math: Necessary and sufficient factors in stereotype threat. *Journal of Experimental Social Psychology, 35*(1), 29–46.

Astin, A. W. (1993). What matters in college? Four critical years revisited. San Francisco: Jossey-Bass.

Astin, A.W., Vogelgesang, L.J., Ikeda, E.K., & Yee, J.A. (2000). How service learning affects students. Los Angeles: Higher Education Research Institute, University of California.

Bacchini, F., & Lorusso, L. (2019). Race, again: how face recognition technology reinforces racial discrimination. *Journal of Information, Communication and Ethics in Society*.

Bandura, A. (1986). The explanatory and predictive scope of self-efficacy theory. *Journal of social and clinical psychology*, *4*(3), 359-373.

Bandura, A (1997). Self-Efficacy: The Exercise of Control. New York: Freeman.

Bandura, A. (1977). Social Learning Theory. Prentice Hall, Englewood Cliffs, N. J. P. O. Connel, D. Pepler, and W. Craig. 1999. Peer involvement in bullying: insight and challenges for intervention. Journal of Adolescence 22, 0238.

Barnir, A., Watson, W. E., & Hutchins, H. M. (2011). Mediation and moderated mediation in the relationship among role models, self- efficacy, entrepreneurial career intention, and gender. *Journal of Applied Social Psychology*, *41*(2), 270-297.

Brattesani, Karen A., Rhona S. Weinstein, and Hermine H. Marshall. (1984). "Student Perceptions of Differential Teacher Treatment as Moderators of Teacher Expectation Effects." *Journal of Educational Psychology*, *76*(2): 236–247.

Bell, T., Alexander, J., Freeman, I., & Grimley, M. (2009). Computer science unplugged: School students doing real computing without computers. *The New Zealand Journal of Applied Computing and Information Technology*, *13*(1), 20-29.

Bell-Watkins, K., Barnes, T., & Thomas, N. (2009). Developing computing identity as a model for prioritizing dynamic K-12 computing curricular standards. *Journal of Computing Sciences in Colleges*, *24*(3), 125-131.

Berk, R. A., Berg, J., Mortimer, R., Walton-Moss, B., & Yeo, T. P. (2005). Measuring the effectiveness of faculty mentoring relationships. *Academic medicine*, *80*(1), 66-71.

Bettin, B., Jarvie-Eggart, M., Steelman, K. S., & Wallace, C. (2020, October). Infusing Computing Identity into Introductory Engineering Instruction. In *2020 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.

Blaney, J. M., & Stout, J. G. (2017, March). Examining the relationship between introductory computing course experiences, self-efficacy, and belonging among first-generation college women. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education* (pp. 69-74).

Blunt, T., & Pearson, T. (2021, March). Exploring the Digital Identity Divide: A Call for Attention to Computing Identity at HBCUs. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (pp. 640-646).

Boyer, K. E., Thomas, E. N., Rorrer, A. S., Cooper, D., & Vouk, M. A. (2010, March). Increasing technical excellence, leadership and commitment of computing students through identity-based mentoring. In *Proceedings of the 41st ACM technical symposium on Computer science education* (pp. 167-171).

Brickhouse, N. W., & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(8), 965-980.

Butler, J. 2001. The question of social transformation. In Women and social transformation, ed. E. Beck-Gernsheim, J. Butler, and L. Puigvert, 1–28. New York: Peter Lang.

Butler, J. (1990). Gender trouble. New York, NY: Routledge.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *44*(8), 1187-1218.

Carpi, A., Ronan, D. M., Falconer, H. M., & Lents, N. H. (2017). Cultivating minority scientists: Undergraduate research increases self- efficacy and career ambitions for underrepresented students in STEM. *Journal of Research in Science Teaching*, *54*(2), 169-194.

Castro, B., Diaz, T., Gee, M., Justice, R., Kwan, D., Seshadri, P., & Dodds, Z. (2016, February). MyCS at 5: Assessing a middle-years CS curriculum. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education* (pp. 558-563).

Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. *Journal of personality and social psychology*, *97*(6), 1045.

Cummings, R. T., Huff, E. H., Mack, N. A., Womack, K., Reid, A., Ghoram, B., ... & Gilbert, J. E. (2020). An exploration of black students interacting with computing college and career readiness vlog commentary social media influencers. *Computing in Science & Engineering*, *22*(5), 29-40.

Dahlberg, T., Barnes, T., Buch, K., & Bean, K. (2010). Applying service learning to computer science: attracting and engaging under-represented students. *Computer Science Education*, *20*(3), 169-180.

Dahlberg, T., Barnes, T. and Rorrer, A. The STARS Leadership Model for Broadening Participation in Computing. In Proceedings of the IEEE Frontiers in Education Conference, 2007, 17-22.

Denner, J., Lyon, L. A., & Werner, L. (2015, April). Does gender matter? Women talk about being female in college computing classes. In *Proceedings of the Third Conference on GenderIT* (pp. 44-48).

Denning, P. J., Comer, D. E., Gries, D., Mulder, M. C., Tucker, A., Turner, A. J., & Young, P. R. (1989). Computing as a discipline. *Computer*, *22*(2), 63-70.

Dempsey, J., Snodgrass, R. T., Kishi, I., & Titcomb, A. (2015, February). The emerging role of self-perception in student intentions. In *Proceedings of the 46th ACM technical symposium on computer science education* (pp. 108-113).

DiSalvo, James B., Yardi, S., Guzdial, M., McKlin, T., Meadows, C., Perry, K., & Bruckman, A. (2011, May). African American men constructing computing identity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2967-2970).

Dou, R., Hazari, Z., Dabney, K., Sonnert, G., & Sadler, P. (2019). Early informal STEM experiences and STEM identity: The importance of talking science. *Science Education*, *103*(3), 623-637.

DuBow, W., Kaminsky, A., & Weidler-Lewis, J. (2017). Multiple factors converge to influence women's persistence in computing: A qualitative analysis. *Computing in Science & Engineering*, *19*(3), 30-39.

Ellemers, N., Spears, R., & Doosje, B. (1999). *Social identity* (p. 144). Blackwell: Oxford.

Eglash, R. (Ed.). (2004). *Appropriating technology: Vernacular science and social power*. U of Minnesota Press.

Falcone, T. M. (2011). Toward a new model of student persistence in higher education. Paper presented at the Annual Meeting of the Association for the Study of Higher Education, Charlotte, NC.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of research in science teaching*, *47*(8), 978-1003.

Garcia, A., Ross, M., Hazari, Z., Weiss, M., Christensen, K., & Georgiopoulos, M. (2018). Examining the computing identity of high-achieving underserved computing students on the basis of gender, field, and year in school. *Collaborative Network for Engineering and Computing Diversity (CoNECD)*.

Gee, J. P. (2000). Chapter 3 : Identity as an Analytic Lens for Research in Education. *Review of Research in Education*, *25*(1), 99–125.

Gilbert, J. 2001. Science and its 'other': Looking underneath 'woman' and 'science' for new directions in research on gender and science education. Gender and Education 13: 291–305.

Godwin, A., Potvin, G., Hazari, Z. and Lock, R., 2016. Identity, critical agency, and engineering: An affective model for predicting engineering as a career choice. Journal of Engineering Education, 105(2), pp.312- 340.

Goldston, M., & Kyzer, P. (2009). Teaching evolution: Narratives with a view from three southern biology teachers in the USA. *Journal of Research in Science Teaching, 46*, 762–790.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. Journal of personality and social psychology, 102(4), 700.

Guiffrida, D. A. (2006). Toward a cultural advancement of Tinto's theory. *The Review of Higher Education, 29*(4), 451–472.

Hampton, L., Cummings, R., & Gosha, K. (2019, June). Improving Computer Science Instruction and Computer Use for African American Secondary School Students: A Focus Group Exploration of Computer Science Identity of African American Teachers. In *Proceedings of the 2019 on Computers and People Research Conference* (pp. 78-84).

Hausmann, L. R., M., Schofield, J. W., & Woods, R. L. (2007). Sense of belonging as a predictor of intentions to persist among African American and white first-year college students. *Research in Higher Education, 48*(7), 803-839.

Z. Hazari, G. Sonnert, P. M. Sadler, and M. C. Shanahan. 2010. Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research In Science Teaching* 47, 8 (2010), 978–1003.

Holland, D., & Lave, J. (2001). *History in person: Enduring struggles, contentious practice, intimate identities*. Santa Fe, NM: School of American Research Press.

Holloman, T., London, J., Lee, W. C., Pee, C. M., Ash, C. H., & Watford, B. (2021). Underrepresented and Overlooked: Insights from a Systematic Literature Review about Black Graduate Students in Engineering and Computer Science. *IJEE International Journal of Engineering Education*, *37*(2).

Hogg, M. A. (2003). Social identity. In M. R. Leary & J. P. Tangney (Eds.), Handbook of self and identity (pp. 462–479). The Guilford Press.

Jenkins, R. (2014). Social identity. Routledge. London.

Kaminsky, S. E., & Behrend, T. S. (2015). Career Choice and Calling: Integrating Calling and Social Cognitive Career Theory. *Journal of Career Assessment*, *23*(3), 383–398.

Kapoor, A., & Gardner-McCune, C. (2019, July). Understanding CS undergraduate students' professional identity through the lens of their professional development. In *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 9-15).

Kinnunen, P., Butler, M., Morgan, M., Nylen, A., Peters, A. K., Sinclair, J., ... & Pesonen, E. (2018). Understanding initial undergraduate expectations and identity in computing studies. *European Journal of Engineering Education*, *43*(2), 201-218.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lehman, K. J. (2019, February). An untapped recruitment pool: Undecided students in CS1 courses. In *2019 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)* (pp. 1-8). IEEE.

Barker, L. J., Snow, E., Garvin-Doxas, K., & Weston, T. (2006). *Recruiting middle school girls into IT: Data on girls' perceptions and experiences from a mixed-demographic group*. na.

Lent, R. W., Lopez, F. G., Sheu, H. B., & Lopez Jr, A. M. (2011). Social cognitive predictors of the interests and choices of computing majors: Applicability to underrepresented students. *Journal of Vocational Behavior*, *78*(2), 184-192.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of vocational behavior*, *45*(1), 79-122.

G. H. RW. Lent, SD. Brown, "Social cognitive career theory," in Career choice and development 4, 2002, pp. 255–311.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. *Career choice and development*, *4*(1), 255-311.

Lundberg, G. M., & Ness, I. J. (2020, October). First year students' imagination of future employment: identity as an important employability aspect. In *Proceedings of the 9th Computer Science Education Research Conference* (pp. 1-7).

Mahadeo, J., Hazari, Z., & Potvin, G. (2020). Developing a computing identity framework: Understanding computer science and information technology career choice. *ACM Transactions on Computing Education (TOCE)*, *20*(1), 1-14.

McCune, V., & Hounsell, D. (2005). The development of students' ways of thinking and practising in three final-year biology courses. *Higher Education*, *49*(3), 255-289.

McGee, E. O. (2016). Devalued Black and Latino racial identities: A by-product of STEM college culture?. *American Educational Research Journal*, *53*(6), 1626-1662.

Morelock, J. R. (2017). A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement. *European journal of engineering education*, *42*(6), 1240-1262.

Marcia, J. E. (1966). Development and validation of ego-identity status. *Journal of personality and social psychology*, *3*(5), 551.

Margolis, J., Estrella, R., Goode, J., Holme, J. J., & Nao, K. (2017). *Stuck in the shallow end: Education, race, and computing*. MIT press.

Nelson, W., Cummings, R. T., & Gosha, K. (2019, October). A Qualitative Investigation on the Effectiveness of a Computing Identity Development Emailing List for African American Computer Scientists. In *2019 IEEE Frontiers in Education Conference (FIE)* (pp. 1-7). IEEE.

Pantic, K., & Clarke-Midura, J. (2019). Factors that influence retention of women in the computer science major: A systematic literature review. *Journal of Women and Minorities in Science and Engineering*, *25*(2).

Peters, A. K., & Pears, A. (2013, March). Engagement in Computer Science and IT--What! A Matter of Identity?. In *2013 Learning and Teaching in Computing and Engineering* (pp. 114-121). IEEE.

Pugh, K. J., Linnenbrink-Garcia, L., Koskey, K. L. K., Stewart, V. C., & Manzey, C. (2010). Motivation, learning, and transformative experience: A study of deep engagement in science. *Science Education, 94*(1), 1–28.

Rodriguez, S. L., & Lehman, K. (2017). Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory. *Computer Science Education*, *27*(3-4), 229-247.

Santolucito, M., & Piskac, R. (2020, February). Formal Methods and Computing Identity-based Mentorship for Early Stage Researchers. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 135-141).

Settles, I.H. When multiple identities interfere: The role of identity centrality. *Personality and Social Psychology Bulletin*, 30, 4 (2004), 487-500.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African-Americans. *Journal of Personality and Social Psychology*, 69, 797-811.

Stone, J., Lynch, C. I., Sjomeling, M., & Darley, J. M. (1999). Stereotype threat effects on Black and White athletic performance. Journal of Personality and Social Psychology, 77(6), 1213–1227.

Shoaib, H., Cardella, M., Madamanchi, A., & Umulis, D. (2019, October). An investigation of undergraduates' computational thinking in a sophomore-level biomedical engineering course. In *2019 IEEE Frontiers in Education Conference (FIE)* (pp. 1-4). IEEE.

Taheri, M., Ross, M., Hazari, Z., Weiss, M., Georgiopoulos, M., Christensen, K., ... & Chari, D. (2018, October). A structural equation model analysis of computing identity sub-constructs and student academic persistence. In *2018 IEEE Frontiers in Education Conference (FIE)* (pp. 1-7). IEEE.

Taheri, M. (2019, January). Exploring computing identity and persistence across multiple groups using structural equation modeling. In *American Society for Engineering Education (ASEE) Conference Proceedings*.

Thomas III, E. N. (2005). *The effects of an ethnic-based mentoring model on college adjustment, grade point average, and retention among first-year African American college students attending a predominantly White institution*. Michigan State University.

Tytler, R. (2014). Attitudes, identity, and aspirations toward science. Handbook of research on science education, 82-103.

Von Humboldt, W. (2000). Theory of Bildung. *Teaching as a reflective practice: The German Didaktik tradition*, 57-61.

Walton, G. M., & Cohen, G. L. (2007). A question of belonging: race, social fit, and achievement. *Journal of personality and social psychology*, *92*(1), 82.

Widdicks, K., Ashcroft, A., Winter, E., & Blair, L. (2021, September). Women's Sense of Belonging in Computer Science Education: The Need for a Collective Response. In *United Kingdom and Ireland Computing Education Research conference.* (pp. 1-7).

Wong, B. (2016). 'I'm good, but not that good': digitally-skilled young people's identity in computing. *Computer Science Education*, *26*(4), 299-317.

Zahedi, L., Batten, J., Ross, M., Potvin, G., Damas, S., Clarke, P., & Davis, D. (2021). Gamification in education: a mixed-methods study of gender on computer science students' academic performance and identity development. *Journal of Computing in Higher Education*, 1-34.

Zander, C., Boustedt, J., McCartney, R., Moström, J. E., Sanders, K., & Thomas, L. (2009, August). Student transformations: are they computer scientists yet?. In *Proceedings of the fifth international workshop on Computing education research workshop* (pp. 129-140).

Figure 1

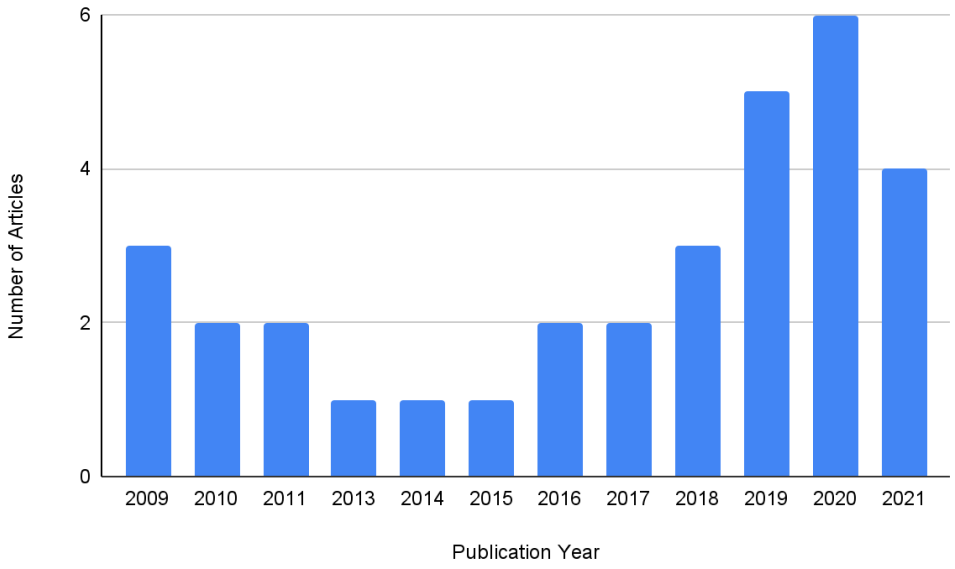

Figure 1. Number of Articles by Publication Year

Table 1

Table 1. Keyword Searches across Databases

	Scopus	ACM DL	ERIC
Computing Identity	X	X	X
Computing Belonging			X
Undergraduate Identity		X	

Table 2

Table 2. Summary of Articles

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M.	2009	*Journal of Personality and Social Psychology*	Ambient belonging: how stereotypical cues impact gender participation in computer science	Quantitative	175 college students	Women	Sense of belonging: Ambient belonging (Astin, 1993)	3 different studies to investigate the effect of male artifacts in computing spaces on women's sense of belonging	Male artifacts like star trek posters in computing spaces can discourage women from participating in computing even in all female cohorts.
Bell-Watkins, K., Barnes, T., & Thomas, N.	2009	*Journal of Computing Sciences in Colleges*	*Developing computing identity as a model for prioritizing dynamic K-12 computing curricular standards*	Framework Development	N/A	No	None	Uses Students and Technology in Academia, Research, and Service (STARS) and Thomas principles for mentoring success to develop a computing identity framework	Propose Computing Identity Framework Model that can be used for the SPE (Standards Prioritization Engine) for developing and prioritizing K-12 computing standard
Zander, C., Boustedt, J., McCartney, R., Moström, J. E., Sanders, K., & Thomas, L.	2009	*ICER '09*	*Student transformations: Are they computer scientists yet?*	Qualitative	108 computing majors in the second half of their degree programs from the USA, UK, and Sweden	No	Social Constructivism (Lave & Wenger, 1991) Ways of thinking and processing (McCune & Hounsell, 2005)	Students were asked to identify a computing concept that transformed the way they saw computing and describe that transformation, and then the researchers performed qualitative content analysis.	Four major categories of computer science identity: professional computer scientist or software developer, CS as a tool that has applications, and CS as an intellectual discipline. Level of CS identity varied widely, with some identifying more as students, but those further along identifying with the broader community, and this can be fueled by learning certain concepts.
Boyer, K. E., Thomas, E. N., Rorrer, A. S., Cooper, D., & Vouk, M. A.	2010	SIGCSE '10	*Increasing technical excellence, leadership and commitment of computing students through identity-based mentoring*	Quantitative	84 students from seven institutions in the STARS Alliance, who had participated in the Computing Identity Mentoring program or another mentoring program.	No	Identity-based mentoring (Dahlberg et al, 2005; Thoms, 2005)	Sent out pre- and post-surveys of both Computing Identity Mentoring students and students who had participated in other mentoring programs at seven institutions across the STARS Alliance	Participating in a mentorship program was beneficial for the students' computing identity in developing their confidence, technical skills and knowledge, and committing to a career in computing and knowing they'll get a job they like

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Dahlberg, T., Barnes, T., Buch, K., Bean, K.	2010	*Computer Science Education*	*Applying service learning to computer science: Attracting and engaging under-represented students*	Quantitative	37 university students in a Leadership Seminar at the Computing College	Women, African American, Hispanic	Service Learning (Astin, 2000)	Measured self-efficacy with Longitudinal Assessment of Engineering Self-Efficacy and replaced engineering with computing, A subscale consisting of three computing-specific self-efficacy items was created from these items. Similarly, three identity items from LAESE were adapted to create a ‘‘computing identity’’ subscale. The authors also developed a questionnaire to measure leadership/team skills.	Students in the program had a high sense of computing efficacy and identity, and there was a significant difference between them and the control for identity, but not efficacy. This is partially due to the opportunity to work with faculty, peers, and people who look like them. Student involvement in service learning may affect computing identity more than it affects computing efficacy.
James DiSalvo, B., Yardi, S., Guzdial, M., McKlin, T., Meadows, C., Perry, K., & Bruckman, A.	2011	*CHI '11*	*African American males constructing computing identity*	Mixed Methods	23 male African American high school Glitch program participants	African Americans	Disidentification (Eglash, 2004)	Pre and post tests and surveys were administered and the Wilcoxon rank-sum test was done to analyze comparisons. Interview and focus groups were also conducted to gather qualitative data on participant experiences	Social structures and their influence on computing identities must be considered. Newcomers benefit from having the social support in communities of practice in order to build interest. Computing contextualized as a career and the social status it holds also helps, and contributes to building an identity
Abbiss, J	2011	*Gender and Education*	*Boys and Machines: Gendered Computer Identities, Regulation and Resistance*	Qualitative	Three separate IT classes at Kahikatea High School in New Zealand	Women	Social Constructivist post positivist feminist in ICT (Gilber, 2001; Butler, 2001)	Collected audio records of classroom conversations, notes from lesson observations, and interviews with teachers and with student pairs. To analyze the data, constructed descriptions of individual students' experiences of specialist IT courses, and also analyzed field texts thematically.	Students hold strongly held gendered perceptions of computer use, and sort uses into three categories: expert, aspiring, and competent, with girls generally identifying as competent.
Peters, A. K., & Pears, A.	2013	*LaTiCE '13.*	*Engagement in computer science and IT - What! A matter of identity?*	Qualitative	149 novice students of the Computer Science and IT engineering programme at Uppsala University	No	Social theory of learning/ Community of practice/student epistemological development (Lave & Wenger, 1991)	Collected reflections in which the students reflect on their choice of study program, goals, and expectations for education. Performed thematic analysis, iterative coding, and explorative deductive analysis on the reflections.	There are two primary groups within the students: those focusing on computers/applications, and those focusing on technology in society, and are very different from where they derive their meaning for computing; higher education is more significant for the second group, as they are looking for more than just skill, which is the primary focus of the first group.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Peters, A. K., & Rick, D.	2014	WiPSCE '14	Identity development in computing education: theoretical perspectives and an implementation in the classroom	Framework Development	17-year-old students enrolled in a Computer Science in Germany	No	Identity/Bildung (self-development/world disclosure) (von humboldt, 2000; Situated Learning Lave & Wenger, 1991)	Integrate a psychosocial and a sociocultural perspective on identity development, and then perform example project work in a school	The theoretical framework can help understand parts of learning beyond knowledge acquisition and design situated learning environments and experiences that foster identification processes and participation in group activities
Denner, J., Lyon, L. A., & Werner, L.	2015	*GenderIT '15*	*Does Gender Matter? Women Talk about Being Female in College Computing Classes*	Qualitative	70 women taking an introductory computer science class at either a university or community college	Women	Identity (Settles, 2004)	Data from online posts and interviews were collected and organized into major themes.	Being female fell into one of three categories in relation to CS: irrelevant, motivational, or incompatible, with irrelevant being the primary category. Thus, a gender focus may no longer effectively increase female persistence in CS.
Wong, B	2016	*Computer Science Education*	*I'm good, but not that good': digitally-skilled young people's identity in computing*	Qualitative	32 teenagers enrolled in a fully funded computing summer school in Britain	No	Identity (Butler, 1990)	Semi-structured interviews were transcribed and coded iteratively, then analysed through identity discourses of computing.	There is a mismatch between the computing identities of the digitally skilled youth and the assumed identities of computing professionals
Castro, B., Diaz, T., Gee, M., Justice, R., Kwan, D., Seshadri, P., & Dodds, Z.	2016	SIGCSE '16	MyCS at 5: Assessing a Middle-years CS Curriculum	Quantitative	3973 US grades 4-10 students both enrolled or not enrolled in MyCS courses	Women, Black/African American, Latina/o, Native American, Multiracial	None	Three times in 2014-15, in Sep., Dec., and May, partnering teachers asked their students to complete a nine-question survey elaborating computational identity, which was measured on a Likert scale, and differences were analyzed	MyCS does not bolster students' positive computational identities more than the control, but it does offer a home for engaging those students – from a representative cross-section of the surrounding district – who identify significantly more positively with computing, as well as leading to a deeper institutional identification with computing
Rodriguez, S. L., & Lehman, K.	2017	*Computer Science Education*	*Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory*	Literature review	Various populations from different sources of literature to explore, define, and contextualize computing identity	Women; URMs	Identity development/ sense of belonging (Chervan, 2009; Goldston & Kyzer, 2009; Holland & Lave, 2001)	Cites other literature to explore and flesh out the definition of computing identity, then lists practical ways it could be applied.	An intersectional computing identity definition that takes into account women and URM is necessary to allow for intersecting personalities and to inform research and practice

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Dubow, W., Kaminsky, A., Weidler-Lewis, J.	2017	*Computing in Science & Engineering*	*Multiple Factors Converge to Influence Women's Persistence in Computing: A Qualitative Analysis*	Qualitative	64 women (winners and nominees of the NCWIT Award for Aspirations in Computing (AiC))	Women	Sense of belonging (L.J. Barker et al., 2006)	In-depth interviews held either individually or within a focus group. Applied both content-based codes as well as codes that were emergent constructs in the data.	Multiple supportive factors that contribute to women intending to pursue, or actually pursuing, computing include having sufficient exposure to learn computing skills, whether in school or out of school; sufficient community support, including teachers, parents, and peers; and respect and encouragement from other individuals in their computing journey.
Kinnunen, P., Butler, M., Morgan, M., Nylen, A., Peters, A. K., Sinclair, J., & Pesonen, E.	2018	*European Journal of Engineering Education*	*Understanding Initial Undergraduate Expectations and Identity in Computing Studies*	Qualitative	First year CS students in Finland, Sweden, and the UK	No	Expectation (Brattesani, 1984)	Students filled out surveys at the beginning of their studies answering five open-ended questions. A collaborative inductive content analysis was used to create meta- and sub-categories.	Supporting students to develop identity within CS requires presenting different engagement modes students can negotiate their identity with. Additionally, shifting the perception of CS away from only programming to its larger societal role might help recruit more diverse students.
Garcia, A., Ross, M., Hazari, Z., Weiss, M., Christensen, K., & Georgiopoulos, M.	2018	*Collaborative Network for Engineering and Computing Diversity (CoNECD)*	*Examining the Computing Identity of High-Achieving Underserved Computing Students on the Basis of Gender, Field, and Year in School*	Quantitative	93 full-time high-achieving underserved students in computing engineering, computer science, and information technology	Women	STEM identity (Goodwin et al., 2016)	Exploratory factor analysis used to assess validity of sub-constructs, and Kruskal-Wallis non-parametric tests to compare groups	Female students had significantly lower recognition sub-construct scores and overall computing identity. IT students also had a significantly lower overall computing identity, as well as first year students, who also were significantly lower in their interest and performance/competence sub-constructs.
Taheri, M., Ross, M., Hazari, Z., Weiss, M., Georgiopoulos, M., Christensen, K., & Chari, D.	2018	*2018 IEEE Frontiers in Education Conference (FIE)*	*A structural equation model analysis of computing identity sub-constructs and student academic persistence*	Quantitative	1640 undergraduate students at three metropolitan public institutions	Women	Identity, STEM identity (Gee, 2000, Tyler, 2014)	A quantitative Flit-Path survey was sent to undergraduate students at three universities in Florida and structural equation modeling (SEM) was used to analyze effects of constructs while confirmatory factor analysis was used to validate the construct measures.	Interest had the strongest direct effect on persistence, while beliefs of self-competence were also significant. Recognition was indirectly and directly effective on persistence through interest. Sense of belonging directly affected competence and performance.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Hampton, L., Cummings, R., & Gosha, K.	2019	*SIGMIS-CPR '19*	*Improving computer science instruction and computer use for African American secondary school students: A focus group exploration of computer science identity of African American teachers*	Qualitative	4 African American secondary school STEM teachers in the Metro Atlanta, GA region	African Americans	Sense of Belonging (Walton & Chen, 2007) Self-efficacy (Bandura, 1997)	Used a qualitative focus group. Computing identity was measured as a combination of sense of belonging and self-efficacy, not as a construct of its own, and equivalent to CS identity.	Teachers lack resources and paid training time to teach CS. Some students are burned out by the CS courses that are taught.
Kapoor, A., & Gardner-McCune, C.	2019	Proceedings of 24th Annual ACM Conference on Innovation and Technology in Computer Science Education	Understanding CS Undergraduate Students' Professional Identity through the lens of their Professional Development	Mixed Methods	14 CS/CE undergraduate students	No	Identity status theory (Marci, 1966) SCCT (Lent et al, 2004)	A cross-sectional mixed-method study using a Concurrent Triangulation Design. Recruited a mix of interview participants equally representing gender and academic standing from our survey participants to gather information-rich cases through purposeful sampling, triangulated the data to ensure reliability, before collecting data from multiple institutions on developing a computing professional identity theory.	Found two groups of students, moratorium, who were uncommitted to a specific profession, and achieved, who had committed to a specific profession. This professional identity typically forms in the second or third year.
Pantic, K., & Clarke-Midura, J.	2019	*Journal of Women and Minorities in Science and Engineering*	*Factors that influence retention of women in the computer science major: a systematic literature review*	Systematic Literature Review	Undergraduate women in CS majors	Women	Tinto's model of institutional departure (Tinto, 1993; Falcone, 2011; Giuffreda, 2006)	Keywords 'women', 'computer science', and 'retention' used within ERIC, Education Source, Google Scholar, and ACM Digital Library to find 102 titles for analysis. These studies were included if they addressed the issue of retention of undergraduate women in CS majors (not STEM overall).	Individual - many studies show differences between male and female pre-entry attributes, including less computer and programming experience, less confidence and resource use, and different intellectual and social preferences (e.g. gaming). Redesigned CS courses can help with this, such as contextualized programming for the real world, in addition to same-sex project groups or learning communities Institutional - initial interactions with those in their program must be positive for reinforced persistence, especially with attentive faculty and peers. Female faculty and peer role models and changing departmental culture help with this Societal - concerns of future family-work balance was a large factor, as well as social support from peers, family support, and cultural norms in other countries

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Taheri, M.,	2019	*American Society for Engineering Education, 2019*	*Exploring computing identity and persistence across multiple groups using structural equation modeling*	Quantitative	1640 students in IT, CS, and CE at 3 public Florida universities.	Women	SCCT (Lent et al., 1994, Lent & Brown, 2002)	Quantitative, 22 item survey. Used structural equation model analysis to see how identity sub-constructs contributed to persistence in computing by first performing a confirmatory factor analysis to ensure valid measurements from the model. Then used invariance measurement testing to compare male and female, freshman and senior students and Chi-square difference test to see if comparison was significant.	All sub-constructs (recognition, interest, sense of belonging, and competence/performance) have some impact on persistence in computing, with interest being the most significant direct impact. There are indications that students feeling recognized or like they belong can help towards becoming interested and feeling competent in performing, respectively, which both directly impact persistence.
Lehman, K.J.	2019	*2019 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)*	*An Untapped Recruitment Pool: Undecided Students in CS1 Courses*	Mixed methods	Quantitative data from the Building, Recruiting, and Inclusion for Diversity (BRAID) research project, and interviews were taken from students in introductory computing courses	Women, Black/ African American people, Hispanic/ Latino/a people	Science identity (Carlone & Johnson, 2007)	Drawing from Carlone and Johnson's science identity theory, applied to undecided students in the computing sciences, students in introductory computing courses were interviewed about their experiences in computing.	Undecided students may serve as a good pool from which to recruit women but are not a diverse group in terms of race/ethnicity. It is possible that students from historically underrepresented groups tend to make a commitment to a college major sooner than White and Asian students do, which could explain their lower presence in undecided majors.
Nelson, W., Cummings, R.T., Gosha, K.	2020	*2019 IEEE Frontiers in Education Conference (FIE)*	*A Qualitative Investigation on the Effectiveness of a Computing Identity Development Emailing List for African American Computer Scientists*	Mixed methods	21 members of the African American PhDs in Computer Science (AAPHDCS) listserv	African Americans	Resilience (McGee, 2016)	Survey with 26-item User Experience Questionnaire (UEQ). Semi-structured interviews were conducted to see how effective the listserv was in maintaining participants' resilience in their computing identity.	Computing identity in African American students can be maintained by building a sense of belonging within a community, inspiring optimism, and bolstering feelings of self-efficacy. These can converge to create a model of resilience to possibly help lower attrition rates.

Authors	Year	Journal title	Article title	Type of Study (Quant/Qual, Mixed Methods)	Sample Population	Focus on Minori-tized Group(s)	Theoretical Framing	Methodology	Main Finding(s)
Cummings, R.T. Huff, E.H., MacK, N.A., Womack, K., Reid, A., Ghoram, B., Gosha, K., Gilbert, J.E.	2020	Computing in Science & Engineering	An Exploration of Black Students Interacting with Computing College and Career Readiness Vlog Commentary Social Media Influencers	Mixed Methods	Youtube videos in vlog commentary format, dealing with the graduate school or industry careers in STEM, by an ethnic minority or a woman	Black people	Mentoring (Berk et al., 2005)	First, a synthesis of vlog commentary college and career advisement videos, coding for the quality of advisement, usability, and user experience; second, an advisor effectiveness and user experience survey using a selected Black social media influencer who provides computing college and career advisement; and third, a user experience and interaction preference survey using a selected Black social media influencer.	YouTube influencers could be effective in developing computing identity in Black students, particularly for beginners in the computing field
Mahadeo, J., Hazari, Z., & Potvin, G.	2020	*ACM Transactions on Computing Education*	*Developing a computing identity framework: Understanding computer science and information technology career choice*	Quantitative	1704 students in an introductory physics course at 22 US colleges	Black (African American) people; Hispanic people; Women (Female)	Identity theory (Hazari et al., 2010) Self-efficacy (Bandura, 1999)	Administered a survey to students; nine items in the survey were mapped to the sub-constructs in a computing identity model, and multilevel confirmatory factor analysis was used to evaluate.	All three sub-constructs were significantly positive predictors of students' career choice in CS and IT: interest, performance/competence, and recognition, in order of strength of prediction. There were no significant differences by race, but males have a significantly higher computing identity than female students.
Santolucito, M, Piskac, V	2020	*SIGCSE '20*	*Formal methods and computing identity-based mentorship for early stage researchers*	Qualitative	Four high school and five undergraduate students involved in the lab group's research	No	Identity-based mentoring (Boyer et al., 2010)	Case study of four high school students and five undergraduates who participated in formal methods research in their lab group.	It is important to involve students before their final year of undergrad to increase long term collaboration quality, although this can be difficult, especially when it comes to undergrads. To best encourage computing identity, projects should be non-critical but still contribute significantly. Giving high school and college students research tasks perceived as both difficult and important along with mentoring helps increase computing identity.
Bettin, B., Jarvie-Eggart, M., Steelman, K. S., & Wallace, C.t	2020	2020 IEEE Frontiers in Education Conference (FIE)	Infusing Computing Identity into Introductory Engineering Instruction	Mixed Methods	Master class of ENG1 Students	No	Identity Based Mentoring (Boyer et al., 2010)	Student reflections from engineering course	Work in progress

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Lundberg, G. M., & Ness, I. J.	2020	9th Computer Science Education Research Conference	First year students' imagination of future employment: identity as an important employability aspect	Qualitative	Eight first-year students in a three year program on cybersecurity and infrastructure in the Netherlands	No	Situated learning (Lave & Wenger, 1991)	Semi-structured interviews, recorded, transcribed, and analyzed intuitively	Many students did not know what their dream job was, but imagination could be an important tool in helping them think about it.
Blunt, P.; Pearson, T	2021	SIGCSE '21	Exploring the Digital Identity Divide: A Call for Attention to Computing Identity at HBCUs	Call for Intervention?	First year CS students at HBCUs	Black people	Computing Identity (Dempsey et al, 2015) Situated Learning (Lave & Wenger, 1991)	Position paper	Propose course on The Afro Diasporic Narratives of Computing Identity
Zahedi, L., Batten, J., Ross, M., Potvin, G., Damas, S., Clarke, P., & Davis, D.	2021	*Journal of Computing in Higher Education*	*Gamification in education: a mixed-methods study of gender on computer science students' academic performance and identity development*	Mixed Methods	181 undergraduate CS students	Women	Social Identity theory (Pugh, 2010) Self-efficacy (Bandura, 1977	Used SEP-CyLE: online gamified tool to measure its effects on women in CS's identity development, self-efficacy, and experiences	Gamification is useful for improving performance of both genders. Females perceived SEP-CyLE (Software Engineering and Programming Cyberlearning Environment) more negatively than males, but the intro computer programming class did help female students with understanding their computing identity
Widdicks, K., Ashcroft, A., Winter, E., & Blair, L.	2021	*United Kingdom and Ireland Computing Education Research conference*	Women's Sense of Belonging in Computer Science Education: The Need for a Collective Response	Qualitative	13 undergraduates and postgraduates	Women	Sense of belonging (Cheryan et al., 2009)	Understanding how women perceive sense of belonging	Women shared experiences of not belonging as well as belonging; discussing measures like role models, and identity celebration to encourage belonging
Holloman, T., London, J., Lee, W. C., Pee, C. M., Ash, C. H., & Watford, B.	2021	*IJEE International Journal of Engineering Education*	Underrepresented and Overlooked: Insights from a Systematic Literature Review about Black Graduate Students in Engineering and Computer Science	Quantitative	Literature review	African American graduate students	None	Systematic literature review	Factors impacting students pursuing computing in grad school: student identity, recruiting and persistence and grad school perception