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A Qualitative Investigation of African Americans' Decision to Pursue Computing Science Degrees: Implications for Cultivating Career Choice and Aspiration

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According to Pearson (2002), minority groups are not well represented in science, technology, engineering, and mathematics (STEM) occupations. Among these underrepresented groups are African Americans. To ensure the economic vitality of the STEM workforce in the United States, it is imperative to broaden participation in STEM-related fields and computing sciences in particular (J. F. L. Jackson, Charleston, George, & Gilbert, in press; Moore, 2006; Pearson, 2002). Using the method of grounded theory, the author illuminates the experiences of African American computing aspirants at various levels of academic status (bachelor's, master's, and PhD levels). In doing so, this study identifies the key factors that contribute to study participants' successful pursuit of computing science degrees, thereby pointing toward implications for cultivating occupational choice and career aspirations. Study results include a heuristic model for broadening computing participation.

Keywords: STEM, computer science, African Americans, higher education, broadening participation

The highest paying positions in the U.S. scientific and technological workforces are overwhelmingly held by White men (Moore, 2006). Contrarily, African Americans fill less than 3% of these same science, technology, engineering, and mathematics (STEM)-related occupations, with such workforce participatory patterns predicted to remain relatively unchanged in lieu of efforts to diversify representation in the scientific workforce (Hrabowski & Pearson, 1993; Moore, 2006).

There are many barriers faced by African Americans on their decision to pursue professions within STEM disciplines (Charleston & Jackson, 2011). African Americans are among those underrepresented populations that both historically and consistently demonstrate greater educational needs upon college admittance because they are typically underserved by the K–12 education system as compared with their White counterparts (Ashby, 2006). This population is also more likely to enter the K–12 system without the requisite math and science knowledge to be successful in subsequent education levels and careers, specifically in STEM fields (Charleston & Jackson, 2011; Graham, 1997; Moore, 2006).

The prevalent obstacles that these students encounter during undergraduate, graduate, and postgraduate years can be attributed to a gradual decline in the percentage of African Americans in the most advanced levels of science and engineering (American Council on Testing [ACT], 2006; Ashby, 2006; Graham, 1997). As the aforementioned historical and educational factors perpetuate this underrepresentation of African Americans and impede persistence in STEM-related fields, this qualitative inquiry into the lives of African American men and women in higher education computing sciences provides insights that will positively contribute to this body of research. It seeks to illuminate how participants negotiate their educational trajectories in the traditionally homogeneous field of computing sciences at every educational attainment level.

Literature Review

There are currently record-low numbers with regard to participation in STEM disciplines in the United States. From 1994 to 2003, for ex-

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ample, there was no evidence of increasing employment in engineering and technology-related fields (Ashby, 2006). Moreover, this shortage of skilled workers in these subjects is one that has not been experienced since the mid-1950s (ACT, 2006). Although college enrollment on the whole has increased within the past decade, the number of students acquiring degrees in STEM fields does not align with this rise; on the contrary, this figure has decreased (Gilbert & Jackson, 2007). Statistics gathered by the ACT (2006) indicate that one contributing cause to this decline is a lack of adequate preparation to succeed in STEM-based, college-level coursework. With the proliferation of technology on national, global, and economic scales, preparation in STEM-related fields and the computing sciences is becoming necessary to increase access to an information-based and knowledge-driven workforce (ACT, 2006; Flowers, Milner, & Moore, 2003; Gilbert & Jackson, 2007; Maton, Hrabowski, & Schmitt, 2000; Moore, 2006).

Within STEM disciplines, the computing sciences have surfaced as a vital component of the information age, as computer use surges across the spectrum of modern American culture (Carver, 1994; J. F. L. Jackson, Charleston, George, & Gilbert, in press). The United States, however, can no longer solely rely on White men as the only source of viable scientific and technical talent if it is to remain internationally competitive and keep up with labor market demands (Gilbert & Jackson, 2007; J. F. L. Jackson et al., in press). Although the U.S. government has passed legislation to assist in the educational equity of African Americans in the form of affirmative action, this representational disparity remains prominent in STEM disciplines (Maton et al., 2000).

Research (Margolis, Estrella, Goode, Holme, & Nao, 2008) has demonstrated that relatively few African Americans pursue computing sciences as a field of study or profession because of a lack of adequate K–12 education, devoid of requisite institutional encouragement, educational opportunities, and adequate preparation that would serve to cultivate an interest in the field. Although there has been a significant increase in the number of quality computers in less affluent communities, ones in which students of color are in the majority, these computers are used to perform remedial tasks that typically do not cultivate further interest in computers or the computing sciences (Margolis et al., 2003; McAdoo, 1994).

Although existing literature on the subject (Margolis et al., 2003) shows that K–12 students from diverse backgrounds are generally engaged with technology through music, video, graphic arts, and the Internet, interdisciplinary connections between computing sciences and these activities are rarely presented in such a manner that promotes academic or professional interest. The research further demonstrates the lack of applicable technology-based curriculum supplements that could potentially spark student interest in the computing sciences within non–computing-science-related courses that are popular among students (Margolis et al., 2003).

Previous research (MacLachlan, 2006) also presents an argument for integrating additional programs and initiatives to increase successful matriculation of African Americans into STEM-related disciplines. These programs would guide students from undergraduate programs through doctoral education with the intent of grooming them for STEM and computing science faculty and research positions. Since 1998, African Americans have yet to account for more than 2.0%, 1.4%, and 0.7% of the assistant, associate, and full professor positions in the computer sciences, respectively. African Americans have also never accounted for more than 2% of PhD graduates in computing science in a single year over this same time period (J. F. L. Jackson, Charleston, et al., in press). These figures are important to consider in light of the fact that African Americans embody 12.9% of the U.S. population (U.S. Census Bureau, 2008).

To specifically address the gaps in representation within the computing sciences, the National Science Foundation developed the Broadening Participation in Computing program in 2005. Its purpose is to augment the number of permanent residents and underrepresented U.S. citizens—defined as women, persons with disabilities, African Americans, Hispanics, American Indians, Alaska Natives, Native Hawaiians, and Pacific Islanders—who participate in computing science-related areas. Although the program is directed toward undergraduates, graduates, and professionals, it also promotes projects for middle school students.

Within the body of literature that pertains to African American involvement in STEM fields, very few results have been reported on other programs or interventions that target this demographic as it relates to computing science. Thus, in this qualitative study, I intended to synthesize prominent factors that contribute to such participation in this discipline. Moreover, this study provided a forum for African American practitioners in the field to speak to the factors that attracted them to STEM and computing science. As such, the primary research question within this study was as follows: "What key factors contribute to African Americans' pursuit of computing science degrees?" This question exposes the educational trajectory of African American computing scientists, and it highlights the relevant experiences that lead to a sustained interest and degree attainment in the field. Likewise, the answers point toward implications and solutions for facilitating computing interest among African American students.

Method

This qualitative study was designed in a manner that enabled a theory to emerge from the data, unlike many other qualitative study designs. As such, this study did not make use of a specific theoretical framework to guide the study, but rather employed the method of grounded theory, enabling a heuristic model to emerge as a result of the study.

Grounded theory embodies the process of collecting and analyzing data simultaneously. This type of data collection process allows for developing theoretical and thematic explanations, which then serve to explain, compare, and trace the development of researched phenomena (Glaser & Straus, 1967; Mason, 1996). This constant, comparative form of data analysis is essential to grounded theory methodology because it allows researchers to keep analysis and theory generation secured within the data (Glaser & Strauss, 1967). The process involves the following steps: (a) comparing the data applicable to each conceptual category, (b) integrating the categories and their properties, (c) delimiting the emergent theory, and (d) writing theory (Jorgensen, 1989).

Conrad, Neumann, Haworth, and Scott (1993) assert four overlapping, iterative stages as they relate to grounded theory. Through this stage process, research is initiated by collecting and coding data into as many categories of analysis as the data allow. These categories parallel those concepts identified by the researcher through the constant comparison of the collected data. This first stage precipitates the researcher's consideration of the theoretical properties of these developing concepts from the start of the study. As the researcher discovers gaps within the developing theory, the second iterative stage involves theoretical sampling, which further guides the data collection process. The third overlapping, iterative stage consists of developing a rudimentary theory, accomplished through additional refinement of pertinent concepts and their relationships. It is in this stage that the researcher attempts to discover data that support or reject key concepts and theoretical propositions. Likewise, this process enables the elimination or modification of concepts in accordance with the depth of support that can be pulled from the data. Following the first three stages, theoretical saturation is accomplished by the emergence of an integrated theory, the fourth and final stage of grounded theory (Conrad et al., 1993).

Grounded theory enables the constant examination of data, which serves to further develop the study, based on emergent themes and concepts. In addition, it informs its observers of intricate details and concerns among study participants, ones that ultimately reveal access variables that allow for incremental change (Glaser, 1999). The flexibility fostered through grounded theory and the constant comparative method helps circumvent diversions that could undermine the study, promoting its credibility at large.

Because the goals of the African American Researchers in Computer Science (AARCS) program—which brings together geographically dispersed African American computing aspirants through annual conferences—were consistent with the goals of this research study, qualitative inquiry using individual interviews were conducted among AARCS participants.

This study endeavored to explore, identify, and examine the key factors that facilitate the desire and pursuit of studying computing sciences among African Americans. The purpose of this research was to illuminate the career pathways of successful African American computing scientists from the perspective of these individuals in an effort to highlight implications for policy, programming, and curriculum modifications. In conjunction with a developed interview protocol, this study's research question elucidated the pertinent factors that contribute to studying the computing sciences. Furthermore, the qualitative inquiry fostered a better understanding of the following concerns with regard to persistence in the computing sciences among African Americans: (a) early exposure to computers, (b) K–12 and college curriculum, (c) extracurricular programs and activities, (d) internships and work experiences, and (e) key role models and positive peer influence.

Conducting individual interviews enabled a deep understanding of participants' computing-related experiences, as opposed to quantitative methods that would fail to uncover the heart of the phenomena under study (Glaser & Straus, 1967). Although there were several advantages to employing a qualitative process in this study, its primary benefit was none other to ascertain participants' views of their own trajectories toward computing sciences degree attainment (Lincoln & Guba, 1985).

A complex scope of the social, environmental, and educational interactions between the individuals and computing science-related factors was facilitated through the design of the study. In addition, the interview method necessitated a protocol instrument that enabled flexibility throughout the process of inquiry, which in turn fostered an element of spontaneity. This factor provided for a more robust data retrieval mechanism, another advantage of qualitative methodology. These aforementioned aspects of research design all promoted rich data with thick description, both of which are qualities required for a valid qualitative research study.

Participants

A total of 37 individual interviews were conducted for which the same protocol was applied. Interviews ranged from 30 to 45 min, one for each individual in the sample. From a percentage standpoint, 22% of interviewees were undergraduate students, 48% were graduate students, and 30% were PhD-minted professors or researchers. In addition, 50% of all participants either attended or were in the process of attending predominantly White institutions, 42% attended historically Black colleges and universities, and 8% attended predominantly Black institutions. All participants were African American and had majored in or were majoring in a computing science-related field, and the average participant age was 28.5 years (see Appendixes A–D).

Participants had family socioeconomic status backgrounds that ranged across the spectrum of categories. Most participants, however, were from middle-income, dual-parent households. In addition, the majority did not have a parent involved in computing sciences. The educational backgrounds of those participants with dual-parent households were similar insofar as they all attained similar levels of educational accomplishment, regardless of socioeconomic status.

Data Analysis

After reviewing the study's audio recordings, transcripts, and notes, I employed a basic qualitative analysis process (Miles & Huberman, 1994). I completed the following steps: (a) applying several word codes to the transcribed interviews; (b) noting reflections and other relative remarks in the right-hand margins; (c) sorting through the data to identify and record similar phrases, patterns, commonalities, and differences; (d) isolating these patterns and processes for the next wave of data collection; (e) gradually expanding a small set of generalizations that address consistencies in the database; and (f) confronting said generalizations with a theory-forming body of knowledge. This six-step process was integral in distilling the collected data into words to form thematic categories.

Coding and Emergent Themes

Open coding was an integral part of analysis in this study. Through first-level coding, I extracted data and placed them in many themes and meaning categories, which enabled me to summarize portions of the data (A. C. Strauss & Corbin, 1990). In addition, analyzing the data through codes achieved the goal of dissecting the interview data in a meaningful way, which in turn helped maintain the relationships of thematic representations (Miles & Huberman, 1994). Through the coding process, the emergence of categories and their theoretical underpinnings began to align and make sense. The theoretical implications that gradually came from the categories that created meaning formed relative patterns. A. C. Strauss and Corbin (1990) posit that pattern coding enables the placement of first-level coding into more concise themes. Likewise, the patterns and thematic representations that emerge embody grounded theory (Glaser & Strauss, 1967). When all the incidents were readily classified and the categories were saturated as represented through the emergence of much regularity, I concluded the data collection and analysis portion of the study (Lincoln & Guba, 1985; A. L. Strauss, 1987).

The interview protocol fostered the development of an organized dialogue between myself and the participants, chronicling the latter's earliest experiences with computers to their current ones as they related to educational or occupational endeavors. Each individual interview transcript was coded, which established thematic meaning between consistencies. I took care not to make assumptions about the interrelatedness of the data prior to observation and analysis, as evidenced by the inductive emergence of themes absent of chronology.

Positionality

This study was designed as a qualitative inquiry into the educational and occupational trajectories of African Americans into the field of computing sciences in an attempt to make meaning of participants' experiences throughout the course of their education. As such, I repeatedly reflected on my own positionality and the impact of my own complex racial, gender, and socioeconomic status, as well as educational identity with regard to interactions with participants and the interpretation of the resultant data. Moreover, I employed inductive data strategies, allowing the data to serve as the foundation of understanding wherein the findings are acutely descriptive and conveyed through direct quotes and thematic analyses.

Validity and Trustworthiness

In an effort to address reliability and validity of the qualitative inquiry within this study, I employed a naturalistic approach. Whereas traditional empirical research addresses validity in terms of reliability, internal validity, and external validity of measures and procedures, the corresponding terms in naturalistic inquiry include audibility, credibility, and fittingness (Guba & Lincoln, 1981). Reliability in qualitative research involves the ability to replicate the study given a similar set of circumstances. Through naturalistic inquiry, I coded the raw data in a manner whereby the contrived themes and theories are not only understood by another individual, but that the individual is able to arrive at a similar conclusion through the consistencies of the coded raw data.

Credibility in this study, in concert with naturalistic inquiry, was achieved by corroborating the structures that made up the study. More plainly, corroboration was ascertained by spending ample time with study participants to check for distortions, which facilitated prolonged engagement with study participants. Likewise, the participants' experiences were explored in sufficient detail, which exemplified persistent observation. In addition, multiple data sources were checked by comparing various forms of data such as digital audio recordings, physical transcriptions, and consultation with other investigators, as well as researcher notes. The aforementioned processes of prolonged engagement, persistent observations, and checking multiple data sources embody the process of triangulation. Rudestam and Newton (1992) assert that peer debriefing, revising working hypotheses throughout the data collection process, clarifying preliminary findings with study participants, and audio-/videotaping the interviews in an effort to compare with other means of data collected are customarily the procedures necessary to ensure the credibility of a study. Through the current study's primary method of individual interviews, triangulation occurred through corroborating persistent observations, checking multiple sources of data through an in-depth literature review, recording field notes, and clarifying categories and narratives among study participants. These processes fostered structural corroboration of the study.

In an effort to address validity among the current study, I attempted to address Wolcott's (1990) nine points to satisfy the correctness or credibility of this qualitative study:

1. Talk a little, listen a lot. I attempted to facilitate a social visit whereby the subject

felt comfortable and I was attentive, speaking when necessary and listening when necessary.

2. Record accurately. I attempted to record precise words when necessary in a timely fashion to avoid misinterpretation of words and behaviors.
3. Begin writing early. I began writing early in an effort to expedite the process of recognizing holes in the data collected or its processes.
4. Let readers see for themselves. I purposed to let others provide input on primary data in an effort to expand the focus of what I observed and interpreted.
5. Report fully. Although I do not report every discrepant detail, I aimed to entertain possible discrepancies and the possible significance of their interpretations.
6. Be candid. I attempted to be subjective throughout the qualitative approach of the study.
7. Seek feedback. I sought feedback throughout the process in an effort to avoid overembellishment or underdevelopment of concepts in the study.
8. Try to achieve balance. I attempted to balance the events recorded in an effort to avoid disproportionate attention given to outliers in the study.
9. Write accurately. I attempted to check for coherence and internal consistencies throughout the crafting of the written study.

In attempting to address these nine points, I aspired to provide validity and credibility through the research process and specifically in the recording and reporting of results.

Results

After analyzing the various forms of data collected in this study, the following categorical themes emerged as factors that led to degree attainment in computing science fields: (a) early exposure to and engagement with computers and computing, (b) positive interaction and computing socialization, (c) galvanizing factors concerning computing sciences, and (d) compulsory considerations for occupational decision making with regard to computing careers. As some of these data do not fit easily in a singular category, there are places in this inquiry in which various themes emerged in more than one category.

Early Exposure and Engagement With Computers and Computing

The participants relayed a variety of earliest experiences with computers. Although initial exposure to computers usually occurred during the primary years, ages 6–11, in most cases, these introductions were not typically accompanied by sustained engagement. In fact, there was an average gap of 6 years between initial exposure and sustained engagement with computers among study participants. Preliminary contact with computers was facilitated by two major factors: school exposure and parental purchase. The term *classroom exposure* was purposefully avoided, as some participants whose schools introduced them to computers did not have the devices in their classrooms but had only a handful for the entire school at large. One female graduate student offered a similar sentiment while addressing her initial exposure to computers:

> Elementary school, it was an old computer; the gifted students were allowed to use the computers. It was a select group. . . . It was a gap, I saw and didn't think much of it [a computer] until my dad bought one, and we were hooked.

Although there was considerable variation with regard to the grade levels during which participants were initially exposed to computers, as well as the degrees to which they were actively engaged, the types of initial contact within school settings were strikingly similar. Such initial remedial engagements were consistent with prior research studies in which these experiences failed to ignite further interest in computing among underrepresented students (Margolis et al., 2008). Likewise, these types of early engagement were sometimes reflective of experiences in which participants' households contained computers as well. The most salient activities involved in early engagement with computers were (a) keyboarding/word processing, (b) video/educational gaming, and (c) class assignments. These experiences are considered to be remedial engagement because the participants typically described them to be uneventful and boring, failing to facilitate further interest in computing. This female graduate student participant's assertion demonstrates these notions:

> We got a Gateway desktop when I was in 7th–8th grade. I didn't really use it a lot but when I used it, I typed up papers. It was a one-time thing until I got to high school and I had to type papers, do PowerPoint, and so forth. . . . Actual work on it.

Even in the case of classroom exercises and assignments that necessitated the use of computers, many participants still did not develop further interest in computing. These activities were presented more as duties or responsibilities, ones that did not articulate the computer's power or range of utility. In addition, gaming was a significant aspect of participants' early engagement with computers in class settings, as students described how they were often rewarded with computing time for gaming purposes. These activities did not induce sustained engagement however, nor did they induce participants to explore computing further. Although these assertions were often not explicit in the data, they were often alluded to through colloquial phrasing, as in the following statement by a female graduate student, for example, by the term *and that's it*:

> In middle school, it was like three hours every other week and we were doing math programs on the computer. We did problems and exercises on the computer and that's it. My mom got a computer at home a little later but my interactions were still limited.

The earlier the participants were exposed to computers— even if their engagement was to complete remedial tasks, such as word processing—the sooner they began to explore more advanced computing functions. Those participants whose parents purchased computers during their primary years—as well as those participants who were more actively engaged in school at an early age, by third grade specifically—were found to have progressed toward using computers for more high-level applications more quickly.

The majority of the participants did not partake of advanced computing functions such as programming and coding prior to college enrollment. Those participants who did did so through their high school curricula, extracurricular science or technology-based programs, and/or individualized familial support. Although some interviewees were enrolled in computing sciences courses in high school, which facilitated advanced engagement, some respondents still expressed dissatisfaction with the lack of high school opportunities for doing so.

The majority of participants achieved advanced engagement with computing after enrolling in college. Many did not have access to a personal computer prior to this point in their education. Accordingly, the majority of these students had no working understanding of computing sciences as an occupational field prior to college. Therefore, those participants who had not entered undergraduate school with the intent of pursuing a degree in computing sciences made the decision to the contrary only after undergraduate enrollment or when considering graduate school.

Positive Interaction and Computing Socialization

Participants cited a number of positive social interactions as being instrumental in their decisions to pursue computing science degrees. Whereas other research pertaining to STEM disciplines has illuminated negative social influences that deter underrepresented populations from persisting (ACT, 2006; Gilbert, Jackson, George, Charleston, & Daniels, 2007; Moore, 2006), the participants in this study largely described social interactions that aided them in their educational and computing development. Although interviewees had often gained measurable success in computing, this is not to say that barriers related to social aspects of their experiences did not exist. These iterations, however, generally came in the form of retrospective considerations about computing, as well aspects about it that they liked least.

Although some participants cited their own curiosity as a contributing factor toward an increased and more focused pursuit of computing, many credited their parents, professors, advisors, teachers, and friends as significant influences. These individuals majored in computing sciences, or encouraged, supported, and in some cases sponsored them to do so. These sentiments emerged thematically in the form of positive social interactions and computing socialization, forming three major subthemes: (a) peer modeling or positive peer influence, (b) parental nurturing, and (c) mentorship.

Peer modeling or positive peer influence was extremely salient with regard to persistence in computing. It offered opportunities for socialization among participants, introducing participants to computing sciences, relevant concepts and constructs, and its accompanying educational pipeline. The combination of these factors ultimately sparked sustained interest among the participants. The following assertion by one female faculty participant corroborates the findings related to peer modeling and positive peer pressure and influence:

> Actually, I became really good friends, well it was like five of us, and we actually started finding more things to do, like, different, um, there used to be, like, different tweaks that you could put or even, like, in operating systems like [Windows '95 and '98], like there's a lot of different tweaks that you could probably do, like, our own extra stuff. . . . I actually have one of my friends who, um, I met freshman year as well. . . . We always had this, like, competition about our computers like. . . . What new specs are we gonna buy, so it's kinda like a competitive and feeding-type thing at the same time.

Often, participants cited friends who encouraged them to pursue computing. In many cases, these friends were academically or occupationally senior to the interviewees, typically involved in more advanced computing activities. The encouragement of these friends, in many cases, persuaded participants to change their college or university major to computing, usually from a related area such as mathematics. One female graduate student stated,

> One of my friends started teaching me about programming C++. The next semester, I took an intro to programming. . . . As an undergrad, I was an applied mathematics person. My friend told me to join the [Computing and Robotics] Olympiad team. I went to the conditional stimulus professor and expressed my interests. . . . She was computer science, and I was math, and I would just sit there and watch her do programming. She was, like, creating stuff that I didn't know was there. And when I got to the computer science class, I said "OK, I might actually want to do this."

Parental nurturing also played a significant role with regard to positive social interaction, primarily through entry and settling into undergraduate education. These positive social interactions often presented themselves in the forms of moral, educational, and financial support. Such development was found to generally begin through computer purchases, progressing into the cultivation of computer savvy through hardware and software purchases. Parental encouragement or sponsorship of supplementary education toward computing or individualized efforts toward computer-related knowledge acquisition—the teaching of programming, for example—also proved to be common.

In addition to peer modeling and parental nurturing, mentorship served as a positive social interaction and socialized participants to the world of computing, contributing to degree attainment outcomes for participants. Mentoring was particularly significant with regard to participants' aspirations toward the highest levels of degree attainment in computing sciences, as study participants often described how they considered withdrawing from computing science programs if not for the intervention of a mentor. In many cases, these mentors provided formal introductions to the field of computing sciences, often through connecting the interviewees with professors and graduate students. In many cases, participants' interests in mathematics catalyzed specific forms of computing-related mentorship because of the intersectionality and direct correlation between the two disciplines. The following statement from a female faculty participant serves as an example of how mentorship positively influences computing persistence toward degree attainment:

> My boss realized someone was getting into these [computer] systems. He asked me if I had been to school. He said, "Keep trying to get in [the computer systems] and tell me when I can't." He gave me books and encouraged me to go to school [for computing sciences] and told me he could not tell them that some kid had hacked the system. He was my first mentor. . . . He [my graduate advisor and mentor] made sure I had funding and had tokens for transportation. He made sure I was able to be present and do what I had to do. Occasionally, he had to push back on people outside of the department, but he was awesome.

Galvanizing Factors to Computing Sciences

Participants described several appealing factors and characteristics about the field of computing sciences. For the majority of the participants, their initial interest in computers stemmed from the Internet, graphics, and gaming. As their understanding of computing deepened, so too did their fascination with computing. Although several participants named very specific computer-related interests such as artificial intelligence and programming, four salient aspects of computing were deemed most compelling: (a) the versatility/interdisciplinary nature of computing sciences, (b) the fact that computing sciences is ever-changing, (c) the discipline's problem-solving aspect, and (d) the utility of the human–computer interaction.

Many participants expressed their attraction to the versatility of computing sciences as they drew connections between computing and other occupational fields. The interviewees felt that the discipline would enable them to explore other areas of interest and additionally noted that computing's adaptability strongly prevents the possibility of disciplinary fatigue or apathy. The participants expressed their satisfaction with the limitless opportunities of computing, ones that would satisfy any interest. This flexibility enables disciplinary mobility, in turn enabling practitioners to explore interdisciplinary occupations. A female faculty participant stated,

> I guess the thing is that I can try anything. I can figure out what that "it" is. How can I turn what I like into a career? By having an advance degree in a science. . . . It's hard to define because it's so fundamental to so many other areas that you can pretty much do anything and find a niche and really enjoy computing.

It is also of note that interviewees cited the ever-changing aspects of computing as galvanizing factors to the discipline. Explaining that they enjoyed participating in a continually advancing society, they noted how computing facilitates the promise of working with new and innovative technologies, often accompanied by expressions regarding the continual desire to learn. Therefore, the opportunity for learning on the whole—and its applications—registers as an essential characteristic of computing sciences. A female faculty participant posited,

> You have so much diversity in what you can do. There's always room to learn, and I think us as PhDs or aspiring PhDs, even graduate students, we strive to learn. We love to learn. We love to continue to learn. And in this field, as compared to a lot of other fields, you're able to grow. Not only . . . you know as fast or as slow as you want 'cause there's always a different aspect of it [computing science] that's either coming out or something that's already out that you haven't, you know, had a chance to get to know. So it's like, it's a, it's a whole world that's, kinda like, you have access to.

Although participants did express enjoyment concerning the process of problem solving, they were more expressive regarding the gratification they received by solving problems. Previous research (L. A. Jackson et al., 2008) has determined that one particularly attractive aspect of computer science among underrepresented populations was immediate gratification. This proved to be true with regard to this study's participants as they expressed satisfaction with the immediate gratification that comes with the ability to find a solution to a number of problems. One male faculty participant said,

> I really loved physics. Solving problems with these formulas and theorems. . . . Computing sciences has this problem-solving aspect, and coding is the tool that you use. So marrying solving a problem with building something and tinkering with it and debugging it and finally making it work . . . I think that's what I liked best. And the sheer fact I still loved computers.

Other interviewees related the field of computing sciences to helping others with functional tasks, such as this female research scientist:

> If you can figure out a way to use it [computation] to physically change or affect something, that's the way I like to use it . . . so it can physically change, for example, kids' learning experiences. Or [it] can physically change the living conditions of people. . . . It's [computing sciences] always challenging you. Seeing how far you can push.

Compulsory Considerations for Occupational Decision Making Toward Computing Careers

Every participant expressed his or her intention to continue in the field of computing sciences educationally, occupationally, or both, with 70% of participants who had not yet attained a PhD expressing an interest in doing so. Although the primary reasons for pursuing educational attainment in computing encompassed a love for computers, the diversity of the field, and a general love of learning among participants, many spoke to the desire to teach and research with regard to current or future occupational aspirations. Although prior modeling played a significant role in facilitating these aspirations—observing the role of the professoriate and research-based job and internship experiences, for instance—an overt goal of the participants was to give back to African American communities and increase computing participation through modeling.

Although monetary considerations were rarely discussed by the students interviewed for this study, their goals and lifestyle aspirations suggested that they expected the field of computing to be lucrative. One participant recalled looking at her resume and realizing the correlation between computing jobs and higher salaries. Other participants expressed the idea of wanting to be on the "high end" of society. These assertions implied that participants felt that their educational endeavors in computing would pay off, with one male graduate student stating, "In order for me to achieve my goals later on, I need [a] PhD, in order to start my research company. I need some credibility behind my name."

Participants listed a variety of reasons for pursuing doctorate degrees: the freedom granted to the professoriate, the accompanying independence of inquiry, the desire to teach future generations, and the autonomy of thinking and engaging with projects related to one's own interests. Many individuals desired to research and work on projects related to their interests without having to answer to someone, and they posited that a PhD would give them such an opportunity. The participants embraced the idea that they could take a project from start to finish with a doctorate degree, and that the degree affords tenure and job security. Likewise, teaching was a goal associated with such attainment. Moreover, participants aspired to achieve the highest level of degree attainment in their field and sought to feed this ambition with the attainment of a doctorate, which would better qualify them to teach, research, and facilitate independent projects. The following remarks by a male faculty participant illuminate these findings:

> I got a PhD because I wanted to teach. I was a part of the Inroads program and did an internship. It did not light a hard fire though. I thought about my professors at Howard and it seemed like they had a good life. [The professors] had fun doing what they were doing, fun environment, very energetic, cool problems. . . . They were helping students get to their potential and I figured the only way to do that was to get a PhD. They had the personal and professional lifestyles that I wanted.

There were certainly cultural and service-based components to participants' aspirations as well. They expressed the limited number of computer scientists of color they encountered throughout their educational and occupational trajectories, also indicating the desire to serve as computing mentors for other underrepresented populations. Several participants sought to make their parents proud by achieving the degree as well. In addition, they felt that by obtaining a PhD in computing sciences as an African American man or woman, they would not only serve to break stereotypes associated with computing sciences, but also achieve some semblance of job security. The following comment from a female faculty participant affirms these findings:

> I got a PhD because I wanted to teach computer science. My dad said that computer thing may work out but if you get a degree in education, you can always teach. Sometime the market can be hostile and can really crush a dream. Down turning and downsizing. . . . I needed to inflation proof myself. I said, "If I get a PhD, I can always teach."

Discussion

Study Overview

This study sought to ascertain key factors that contribute to African Americans' pursuit of computing science degrees. The design of this study varied from previous research (although very limited in scope) related to African Americans and their persistence in computing sciences by determining the career trajectories of current and aspiring computing scientists, rather than those who do not persist or are just in the beginning stages of the pipeline (see Margolis et al., 2003, 2008). In doing so, this study was not only able to gain the experiences of African Americans who have attained the highest occupation and education levels in computing (e.g., PhD professor, researcher, business owner, consultant), and those who are in the undergraduate and graduate pipelines, but the design of this study also allowed me to implicate a heuristic model that serves to facilitate decision making among African Americans about educational and occupational considerations toward computing sciences.

Major findings in this study suggest that the decision to pursue computing sciences degrees among African Americans was dependent on factors that were mainly socially constructed. Although some participants did demonstrate high levels of ambition and self-initiative, these were not salient contributing factors to their actual degree attainment. What proved more salient were the positive social influences that often were the catalyst for not only the introduction to computing sciences among the participants but also the underlying rationale for persistence in the field through degree attainment. These factors can be categorized into four general areas and serve to answer the research question, "What factors contribute to African Americans' pursuit of computing sciences degrees?"

The answer to this question is (a) early advanced engagement with computers and computing, (b) technological incubation, (c) rigorous grounding in science and mathematics, (d) computing-related cohort building, (e) knowledge of interdisciplinary nature of computing, and (f) multifaceted mentorship. These factors assist in the cultivation of an innovative conceptual model that serves to explain and, if given the proper set of circumstances, reproduce educational and occupational decision making to facilitate degree attainment in the computing sciences among African Americans.

Toward a Career-Specific Developmental Model

Most vocational or career development theories posit that vocational choice is a matchmaking process wherein occupational choices are made that not only satisfy individuals' interests and goals but also relate to the skills, abilities, and temperament that the individual possesses (Gottfredson, 2005). In general, "this process requires that young people first learn the relevant attributes of different occupations and of their own developing selves, and then discern which occupations have rewards and requirements that match their still-evolving interests abilities, values, and goals" (Gottfredson, 2005, p. 72). The findings in this study illuminate the fact that ascertaining the relevant attributes of different occupations depends greatly on the accessibility of resources.

Overwhelmingly, the literature that addresses African Americans and vocation is centered on cultural differences that contribute to perceptions about particular careers and occupational attainment (Byars-Winston, 2010). Contrarily, little attention is attributed to cultural variables that account for observed differences. In many cases, the African American participants in this study were not privy to the fact that computing sciences was an educational and occupational field until they were already well into college. This corroborates other studies (e.g., Byars-Winston, 2006, 2010; Cheatham, 1990; Parham & Austin, 1994) that illuminate the unique circumstances regarding the restriction of occupational opportunity confined within minority group status and further stresses the need for interventions that are culturally situated around career development patterns.

According to most career development theories, by the time students reach college age, they will have already discerned which occupations are viable ones to match their skills, abilities, and specific interest. Furthermore, they have already passed critical stages of their development that may have necessitated the acquisition of skills and abilities that may or may not have been available to them, thus eliminating fields such as computing sciences because of lack of knowledge that the field exists or lack of attaining the skills necessary to sustain the pursuit thereof. Although the literature related to race/ethnicity and career choice has indicated that race or ethnicity does not seem to contribute greatly to variations in career aspirations and decision making, perceptions of barriers and career opportunities vary among different racial and ethnic groups (Fouad & Byars-Winston, 2005). As such, even if students indeed possessed the skills and abilities to achieve with regard to computing, their desire or decision making toward computing could be stifled as a result of believing that computing is simply not for them. Therefore, the proposed model does not lend itself to the "matchmaking" process that occurs naturally in a career development conceptual framework. But rather it facilitates the cultivation of a specific career through six constructed developmental phases for a targeted population, namely, the computing sciences for African Americans.

The Computing Career Choice Model: A Six-Phase Model for Decision Making Toward Computing Sciences

The computing career choice model posits that there are six developmental processes that are particularly significant to spark educational and occupational interests in the computing sciences among African Americans. These developmental phases that facilitate the matching of students to computing include (a) early advanced engagement with computers and computing, (b) technological incubation, (c) rigorous grounding in science and mathematics, (d) computing-related cohort building, (e) knowledge of interdisciplinary nature of computing, and (f) multifaceted mentorship (see Figure 1).

Early advanced engagement can be defined as conducting advanced (e.g., programming), non-remedial tasks and assignments related to computing during primary years. Technological incubation involves the nurturing of individuals with regards to encouraging engagement with science and technology by parents, teachers, and other role models from primary school years through undergraduate enrollment. Rigorous grounding in science and mathematics entails the implementation of a robust curriculum through class work and science and technology-based programs as it relates particularly to areas involving mathematics and sciences from pri-

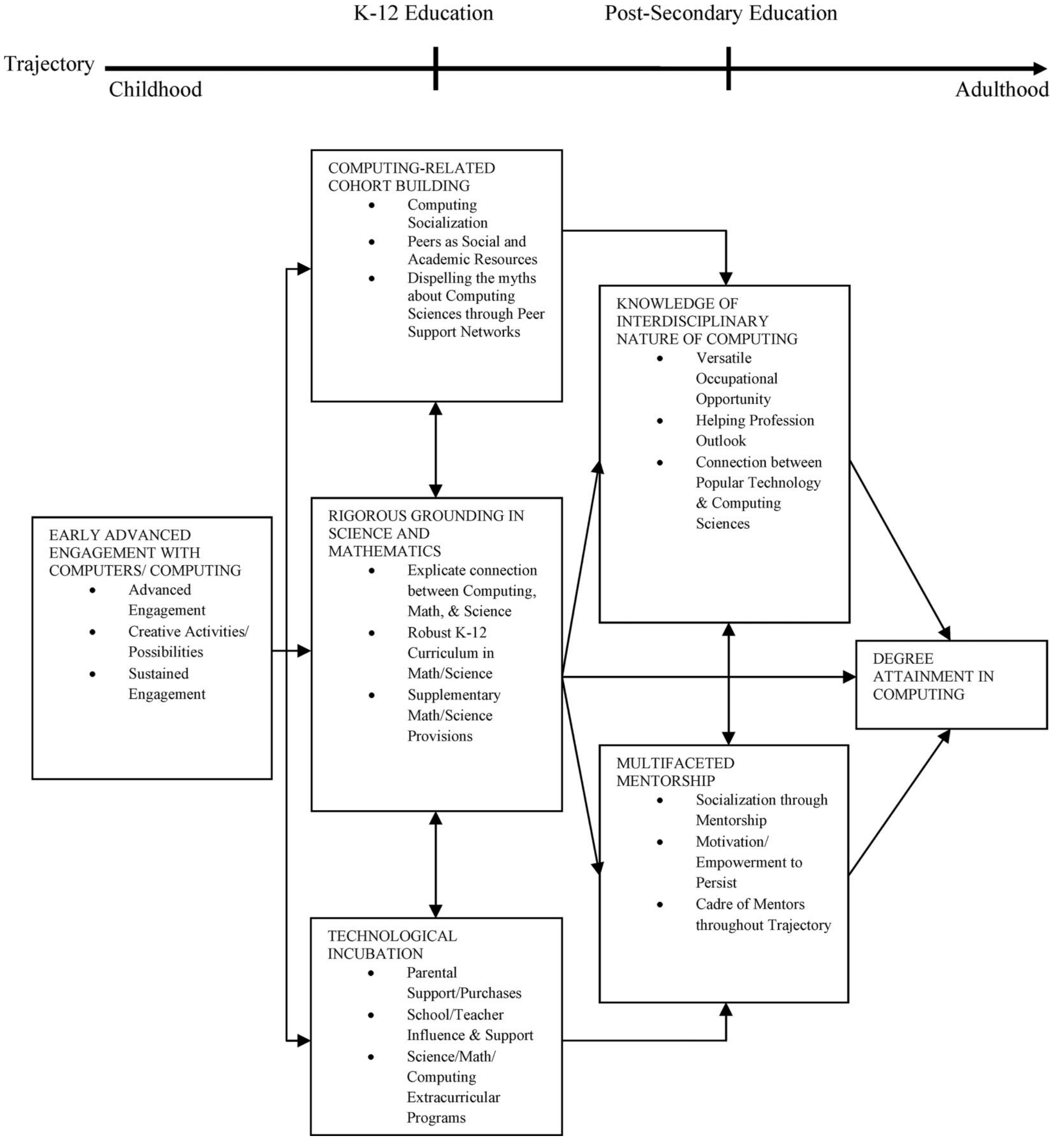

Figure 1. Computing career choice model for African Americans.

mary school years through college. Computing-related cohort building describes the formation of a group of individuals collectively pursuing computing sciences throughout their educational trajectory. Knowledge of the interdisciplinary nature of computing involves informing individuals of the connection between computing sciences and other disciplines. Multifaceted mentorship refers to sustained mentoring from an individual with a vast knowledge of the field of computing throughout the educational and vocational trajectory.

Early advanced engagement with computers and computing. The findings of this study revealed that early exposure to computers alone did not facilitate further interest in computers for the majority of the participants. Furthermore, remedial engagement with computers such as word processing, playing games, and non–computing-related class assignments did little to spark the interest of participants. What did spark their interest in computing was advanced engagement in the form of programming, hardware installation, and information creation (i.e., creating games). Because this advanced exposure facilitated further interest in computing sciences, it is necessary to expose students to these and other types of advanced engagement with computing during their primary years or as early as possible. This engagement serves to facilitate the desire to learn more about computers.

Advanced engagement introduces the prospect of creative possibilities. That is, once information creation is accomplished, this fosters further interest in the limitless possibilities and functions of computers, and how the computer can aid students in bringing their ideas to fruition. It facilitates the opportunity for young African Americans to be owners of technological innovations, which in turn encourages them to pursue further education or knowledge related to computers and computer technology.

Advanced engagement in computing fosters sustained engagement. Remedial engagement such as word processing, keyboarding, and gaming does not facilitate sustained involvement. These remedial tasks lack the necessary intriguing elements of computing that are present in advanced engagement. Advance engagement involves the element of creation, which invokes a recurring desire in African Americans to "do it again." The creation of a product that encompasses an aspect of utility attracts students to not only create additional products, but to repeatedly use their creations, as well as find multiple uses for them. Early advanced engagement with computers and computing catapults an individual's interest in computing sciences, sometimes without that person's knowledge. Hence, the creation of information (i.e., advanced engagement) is a significant precursor to additional computing sciences educational and occupational aspirations. As such, programming code, tools necessary to create knowledge, during this phase gives young African Americans an introduction to the field at a very impressionable age. The earlier and more often African Americans are exposed to and engaged with computing, the more likely they are to persist in computing.

Technological incubation. Technological incubation is an integral aspect of the potential trajectory to computing sciences among African Americans. It involves the support of parents, teachers, and other figures in the uses and implementation of technological applications among African Americans. This incubation occurs through primarily three channels: (a) school (the influence and encouragement of teachers), (b) home (parental encouragement and purchases of computers and related technologies), and (c) extracurricular programming (e.g., science and technology clubs). These constructs can have an immeasurable effect on shaping a young person's academic and career trajectory. Exposing youngsters to various aspects of computing through school, home, and additional activities can in turn expose them to a variety of options, preferences, and proclivities related to computing sciences. As such, this phase is a significant component of the computing career choice model.

Although the home serves as the first line of technological incubation, the school plays a significant role in nurturing African Americans toward technology and computing. The participants in this study often cited schools as their first introduction to computers. School is an ideal place to begin the trajectory toward computing sciences. However, schools must reach beyond encouraging remedial engagement with computers and move toward increasing advanced engagement. Teachers shape children's lives and, often, the teachers serve as role models for students. When teachers encourage and facilitate technology use in the classroom, it not only enhances the learning outcome of students, it also exposes them to technology and its variety of uses, which has the propensity to spark an interest in computing sciences. When teachers facilitate the creation of information and knowledge, African American students become exposed to computing, thus sparking their interest in the field.

Parental nurturing was very instrumental in the trajectories of the study participants. Parental support in the form of verbal and moral encouragement, educational encouragement, and opportunity seeking (e.g., science and computer clubs), as well as financial support (e.g., computer purchasing) has an integral effect on students' disposition toward mathematics, sciences, and computing. It is the support of parents that motivates young African Americans to succeed in the computing sciences. Even where parental predisposition was not geared toward computing, positive encouragement proved to enable the participants, perpetuating their aspirations in computing. The purchase of computers and computer-related products for use in the home benefits young African Americans and enhances the likelihood of computing aspirations. However, where finances do not permit, verbal and moral encouragement serves as a technological incubator if the individual has access to computers elsewhere. Essentially, access to technology is significant to the technological incubation phase.

Extracurricular science, mathematics, and computing programs are significant technological incubators. These programs are specifically geared toward computing, thus focusing all of their programmatic efforts on computing (unlike the multifaceted spaces of schools and homes). As such, these programs facilitate the broad exposure of computing concepts, usually enabling the African American to explore computing sciences more in depth than in other spaces. Accordingly, these programs are powerful influences on educational and career trajectories toward computing. There were very few study participants who matriculated through degree attainment in computing who had not been involved in some extracurricular computing-based program. These programs give students support and encouragement, as well as the technical tools they use to feed as well as facilitate further interest in computing sciences. Therefore, these programs provide technological incubation essential to degree attainment of African Americans in computing sciences.

Rigorous grounding in science and mathematics. Many studies (e.g., Gilbert et al., 2007; Hrabowski & Pearson, 1993; Maton et al., 2000) cite the necessity of a solid foundation in mathematics and sciences in an effort to be adequately prepared for STEM occupations. As computing sciences have risen to the forefront of STEM fields, a strong background in mathematics and science is necessary. Many retrospective considerations posited by the study participants suggested that they would have pursued additional and more advanced courses in preparation for the field of computing sciences. The direct connection between mathematics and science and the field of computing sciences necessitates significant aptitude in math and science, which must be attained throughout the educational trajectory. As such, a solid foundation in science and math fosters the decision to pursue the computing sciences among African Americans.

This phase merits robust K–12 curricula in mathematics and sciences. African American student preparation is often representative of an inadequate educational system. Wherever possible, supplementary education in science and math must be provided. This attainment can take shape in extracurricular math-based programming, tutorial sessions, or robust or supplementary classes in school for science and mathematics. Many of the successful computing sciences participants in this study attended science and technology-based high schools that enhanced their preparation for computing. However, many public schools do not ascribe to these advanced preparatory systems. As such, the aforementioned alternatives must be applied to increase the likelihood of educational and occupational participation in computing sciences among African Americans.

Computing-related cohort building. Computing sciences is a field that requires socialization. That is, to be successful in the field, it is necessary to become indoctrinated with its social and technical aspects. This is most effectively achieved through the formation of groups with individuals of comparable skill level who can navigate through computing together. In these circles (e.g., mandated computing laboratory work, group projects, special programs), African American students feed off of each other and work together on problems related to computing. In a cohort model, group dynamics are established that facilitate teamwork wherein activities, projects, and assignments are completed collaboratively. Likewise, the use of a cohort aids in navigating computing sciences programs and facilitates degree completion.

Computing sciences is a White male-dominated field and, as such, encompasses many constructs that are foreign to African American life. These constructs range from technical application methods to social construction. The best chance for persistence among African Americans is to make use of peers as academic and social resources. The cohort model minimizes alienation and isolation within the field of computing sciences. Likewise, cohorts contribute to the prospect of degree attainment as there is a sense of accountability that is built among African American members.

The field of computing sciences is associated with a variety of myths concerning the field. Many of these myths serve as deterrents for potential African American contributors. Some of these myths include the idea that computing sciences is only for nerds, only for White people, only for geniuses, or that to participate in computing, it is necessary to be isolated and buried in a cubicle. Therefore, the anomaly of participating in advanced-level computing demands a robust support network. Add the social isolation that comes with being an anomaly (African American) in an already analogous field and the necessity of the cohort model becomes more apparent. The participation in a cohort is often the deciding factor for persistence in challenging domains such as computing sciences. Cohort building and participation are central elements of the computing career choice model.

Knowledge of interdisciplinary nature of computing. One of the most salient factors that attracted the African Americans in the study to the field of computing sciences was its versatility. Because computing sciences is connected to nearly every occupational field, computing sciences is interdisciplinary in nature, connecting computing to a multitude of disciplines. This model demonstrates that it is necessary to dispel the above-mentioned myths and make transparent the scope of occupational opportunity prevalent in the field.

Many African American computing scientists persist in the field because it has a "helping" component. That is, it serves to solve human problems. Computing sciences not only assists humans with functional tasks, it is also linked to addressing social inequities (e.g., computing and universal health care, computing applications for increasing disadvantaged learning outcomes). The computing career choice model mandates that African Americans become privy early to the idea that the vast varieties of computing applications are connected to almost every aspect of life. This knowledge expands the scope of opportunity within computing sciences, enabling the realization that computing serves to fill a large variety of occupational considerations.

Most career development theories assert the idea that matchmaking is a process that begins early in the educational trajectories of adolescents (Gottfredson, 2005). Likewise, this matchmaking process is significantly connected to the occupations individuals become privy to through their social networks. Although technological applications are more broadly used in a spectrum of socioeconomic communities (including low income), the connections between the technologies and computing sciences could foster a marriage of the two. More plainly, the knowledge of computing relationships between the technologies used and the field of computing would serve to enlighten African American youth about the diverse aspects of computing, regardless of their status. This knowledge serves to illuminate the interdisciplinary applications of computing, thus demonstrating variation within the field that in turn serves to facilitate further interest in computing among African Americans.

Multifaceted mentorship. African Americans who participate in the field of computing sciences are an anomaly, which in turn necessitates the socialization of aspirants in the field. This socialization process occurs through mentorship. Mentorship is imperative throughout the educational and occupational trajectory. Multifaceted mentorship in computing serves to (a) assist in the academic preparation of African American students, (b) provide social contacts to enhance experiences through the educational trajectory (e.g., computing organizations), (c) provide educational and occupational career advice, (d) provide apprenticeship opportunities, (e) acquire or refer sources of funding, and (f) assist in job search and acquisition. Although these mentorship responsibilities are vast and in-depth, the field of computing sciences necessitates these measures as it is an elite field with few African Americans.

The participants in this study identified mentorship as a key component to their degree attainment. The mentors played an active role in the students' academic and social development as it relates to computing. They served as motivators, encouragers, and in many cases empowered their mentees to persist. As such, mentors not only provide social, moral, and physical support, they also serve as living examples of occupational opportunities in computing.

One mentor should not serve to fill all of these roles. On the contrary, an African American student needs to have a consortium of mentors in an effort for all of these roles to be filled. Likewise, mentorship need not be confined to the specific locality of the African American. With modern technology and the continual advancement thereof, some aspects of mentorship can be accomplished via electronic means. It is the role of mentors to assist African Americans in their navigation of the computing sciences landscape. This phase should occur as early as possible in an effort to facilitate the educational and occupational decision to study computing for African Americans.

Summary of proposed model. The computing career choice model not only offers an overview of the phases within the trajectory of African Americans who persist in computing sciences through degree attainment, but also offers a template to provide a source for facilitating the choice of computing sciences among prospective African American contributors to the field. Although the phases of the model are somewhat chronicled and are meant to begin in the primary years of life, the implementation of these phases later may still result in computing science degree attainment for African Americans. In addition, the order in which the phases take place may not be sequential. However, based on the literature and in conjunction with the results of this study, the exposure of these factors at some point in the educational trajectory facilitates degree attainment in computing sciences among African Americans. Several African Americans in the study did not follow this trajectory, at least not from their primary years. However, the formulation of this model also included retrospective considerations asserted by the participants. In other words, this model also considers what they posited may have helped them achieve their goals in a more efficient manner.

Implications and Recommendations

K–12 education. The limited nature of K–12 education resources, particularly for African Americans, is not sufficient for exposing students to advanced engagement opportunities with computers. This factor creates barriers to the field of computing sciences and other STEM-based fields and is precipitated by poor math and science curricula, deficient computing curricula, and in some cases, poor teaching. School systems must take aggressive steps toward implementing more rigorous math and science courses as well as developing a more comprehensive computing science curriculum. Those systems that do have computing science courses must actively and aggressively recruit African Americans and other underrepresented populations because American racial/ethnic demographics are changing, resulting in millions of unfilled computing-related jobs. Hence, school systems must adequately prepare African Americans to be contributing members of the STEM and computing science workforce.

What may aid K–12 systems in doing so is drawing a connection between popular uses of technology and computing sciences among African American students. Many students are indeed interested in technology such as smart phones, video game systems, and MP3 players, yet they do not connect these devices to computing sciences. K–12 systems, then, are in the unique position to facilitate transitions from these more casual engagements with computing to advanced engagement among targeted populations. Likewise, deploying advanced technology in the classroom can serve several purposes—increasing the learning outcomes of students, facilitating innovative teaching strategies, and positioning students toward computing sciences.

The academy and the industry. Many African Americans are not introduced to computing sciences until after their freshman year in college. By this time, however, African Americans are usually ill prepared for a rigorous college computing curriculum. As such, key decision makers at universities must make connections and build partnerships with local K–12 schools in an effort to familiarize African Americans with computing early in their educational trajectories. By establishing relationships through programmatic efforts, decision makers can build relationships between universities and students, ones that will not only influence higher education enrollment but also influence decisions to move into computing sciences. Many universities possess the resources to establish such programs, but even current programs are not sufficient for the undertaking this study proposes (i.e., significantly broadening computing participation to satisfy current and future workforce demands).

In addition, introductory-level curricula in computing (i.e., weed out courses) must be addressed. These classes need to comprise professors and instructors who are cognizant of the varying learning needs of diverse students. Likewise, administrators should ensure that race- and ethnicity-related assumptions are not instrumental to the way these students are treated. Cultural training may be necessary for computing science teachers to educate instructors as to the various types of pedagogy and learning necessary for different cultural situations. Administrators must also ensure that African American students are not ostracized and marginalized, as social factors can often have a significant impact on the decision to persist in the field. Making sure that every student has an opportunity for success will require administrative attention to both structural and social dynamics that affect the discipline of computing science, specifically the process of teaching and learning.

Similarly, higher education administrators should ensure diverse faculty in computing. Many participants in this study were inspired by African American computing science faculty, and as such, visible members at the highest level of degree attainment and occupation serve to attract more African Americans to the field. In addition, the visibility of these faculty broaden African American participation in the computing sciences and in academic faculty and researcher ranks in general. With many universities having established diversity-related goals, diversity in computing sciences should rise to the forefront of this agenda, as doing so is critical to maintaining the United States' competitive STEM and technological advantage.

Moreover, leaders in the computing industry should take an active role in demystifying computing sciences. Because the media play a central role in creating perceptions about these professionals, industry executives should promote campaigns that dispel misconceptions surrounding the field. In addition, these individuals must foster partnerships and relationships with K–12 institutions, specifically in low-income areas, as well as promote and provide internship opportunities for African American students and other underrepresented populations. These relationships could potentially foster educational and occupational trajectories in computing sciences.

In addition, industry professionals should provide mentoring services to prospective computing participants. Doing so would introduce African Americans, who may not otherwise be exposed to such knowledge, to the wide range of opportunities that exists in computing sciences. This mentorship can come in various forms, including distance mentorship through electronic means. These individuals may be able to tap into a wealth of innovative technologies that could be directed through providing multifaceted mentorship for U.S. students.

Government. Given the U.S. government's recognition of the limited labor force in computing, it is necessary to consider investing more heavily in strategies to broaden participation in STEM-related fields. The National Science Foundation's Broadening Participation in Computing program is an example of the programs that can be instrumental in this endeavor. Financial allotments directed toward increasing the number of computing scientists should be operationalized from every aspect of educational endeavor. Grants could serve as motivation for researchers who would otherwise have little to no incentive for employing intervention programs that target underrepresented groups for involvement in computing. Likewise, the government could provide tax breaks or other benefits to computing companies who successfully broaden participation to diversify the demographic makeup of the industry. Related media campaigns can also illuminate the need for computing scientists of color and could include various aspects of and uses for computing, as well as its interdisciplinary nature, namely connecting computing to other fields that typically attract African Americans, such as "helping professions." When this demand is made more transparent outside of academia and presented in more mainstream terms, this will promote knowledge of the field, dispel the myths associated with computing, and ultimately foster the belief that computing science careers are attainable among the underserved and underrepresented.

The government must also invest in advanced technological teaching and learning tools for K–12 educators, specifically for mathematics, science, and technology fields. Many educational systems that serve underrepresented students suffer from a lack of resources. As such, this effectively separates primary education from the computing sciences, which influences attrition rates in computing. The government should also invoke policies that ensure that K–12 schools have adequate human resources as well. This may include increases in salary for advanced-level teachers and administrators, which may precipitate continued participation in K–12 education as opposed to industry or higher education as it relates to the field of computing.

Parents. As much as possible, parents of African Americans need to nurture their children and help socialize them to use technology by providing them with necessary tools that foster this development. Likewise, parents should consider encouraging their children to explore as many math, science, and technology-based programs as possible. The parents who do so expose their children to computing-related concepts that reach beyond the scope of traditional K–12 education and better prepare them for success in computing science, STEM fields, and the world at large.

It is not always necessary that parents spend large sums of money to provide technological devices for their children as many common items—phones, calculators, video games, and car electronics—employ computers. By informing children of the connections between these technological innovations and computing, parents can encourage their children to become more knowledgeable about technology, thus promoting a greater likelihood of stimulating their interest in computing.

As this study has demonstrated, parental encouragement is extremely effective in facilitating participation in computing sciences. Parents can assist their children's self-efficacy as it relates to computing through positive encouragement. Parents are primary sources of confidence-building and verbal encouragement, and they can facilitate the self-efficacy needed to pursue computing. Likewise, they can serve as a soundboard for their children to receive adequate academic preparation. If parents pay close attention to the courses their children take and ensure that they continue to progress in these courses, specifically mathematics and science, they can provide supplemental education without incurring additional expenses. In sum, they must provide technological encouragement for the sake of promoting interest in computing sciences and technological savvy during a time when many future occupational positions require this skill set.

Future Research

This study looked solely at African Americans persisting in computing sciences, and future research studies could examine nonpersisting students at comparable degree-level aspirations. This article serves as a foundation to establish a robust line of inquiry into nonpersisting undergraduate and graduate experiences related to computing, after which a parallel can be drawn that surmises persistence-encouraging factors through degree attainment. The results would provide implications for ensuring success in pursuing computing sciences among African Americans.

Another prime area for future research would be to qualitatively assess gender differences among African Americans as they relate to participation in computing sciences. This study looked at both male and female African American computing participants; it was not designed to target gender differences, nor were there clear gender delineations. As the future studies begin to further uncover aspects related to broadening participation in computing, the role of gender may prove to be a powerful means to establishing efficient targeted interventions to facilitate increased participation.

Although several researchers are examining computing sciences in K–12 education (Margolis et al., 2008), this work needs to be expanded. Margolis et al. (2008) looked at K–12 computing in a southwestern region of the

United States. This inquiry must be expanded into every region of the United States with the hope of uncovering similarities and differences in K–12 computing practices and curricula on a national scale. Findings of such a study would facilitate interventions specific to the needs of particular school districts with varying demographic representation. Likewise, they would more clearly implicate specific uses and strategies to increase participation in computing among African Americans and other underrepresented groups.

Finally, another possible avenue of study would examine the educational trajectories of White, Asian, and Indian populations as these demographic groups become more visible in computing sciences. A look into these trajectories would illuminate success models that could ideally be suitable for any demographic group as it relates to broadening participation in computing sciences. Although said trajectories into the computing sciences remain an understudied topic, this field may become an increasingly significant topic of study as American society progresses further toward knowledge-based and information-driven technologies.

Conclusion

This study sought to determine key factors that contribute to African Americans' pursuit of computing science degrees. It deviated from previous research related to African Americans and their persistence in computing sciences by determining the career trajectories of current and aspiring computing scientists, as opposed to examining those individuals who do not persist or are just beginning their educational paths (Margolis et al., 2003, 2008). In doing so, this study was not only able to articulate experiences from African Americans who have reached the highest occupation and education levels in computing—and those in the undergraduate and graduate pipelines—but it also allowed implementation of a heuristic model that encourages African Americans to enter computing science disciplines.

Major findings in this study suggest that the decision to pursue computing sciences degrees among African Americans was dependent on socially constructed factors. Although some participants demonstrated high levels of ambition and self-initiative, these were not salient contributing factors to actual degree attainment. What proved more telling were positive social influences that often catalyzed introductions to computing sciences, also serving as underlying rationale for persistence in the field through degree attainment. These factors can be categorized into six general areas and answer the study's original research question, "What factors contribute to African Americans' pursuit of computing sciences degrees?": (a) early advanced engagement with computers and computing, (b) technological incubation, (c) rigorous grounding in science and mathematics, (d) computing-related cohort building, (e) knowledge of interdisciplinary nature of computing, and (f) multifaceted mentorship.

References

American Council on Testing. (2006). *Developing the STEM education pipeline.* Iowa City, IA: Author.

Ashby, C. M. (2006*). Science, technology, engineering, and mathematics trends and the role of federal programs. Testimony before the Committee on Education and the Workforce, House of Representatives* (Report No. GAO-06-702T). Washington, DC: United States Government Accountability Office.

Byars-Winston, A. (2006). Racial ideology in the prediction of social cognitive career variables in Black undergraduates. *Journal of Vocational Behavior, 69,* 134–148. doi:10.1016/j.jvb.2006.02.005

Byars-Winston, A. (2010). The vocational significance of Black identity: Cultural formulations approach to career assessment and career counseling with African Americans. *Journal of Career Development, 37,* 441–464. doi:10.1177/0894845309345847

Carver, B. A. (1994). Defining the context of early computer learning for African American males in urban elementary schools. *Journal of Negro Education, 63,* 532–545. doi:10.2307/2967293

Charleston, L. J., & Jackson, J. F. L. (2011). Future faculty/research scientist mentoring program: Proven coping strategies for successful matriculation of African Americans in computing science doctoral programs. In W. F. Tate & H. T. Frierson (Eds.), *Beyond stock stories and folktales: African Americans' paths to STEM fields* (pp. 287–305). Bingley, UK: Emerald. doi:10.1108/S1479-3644(2011)0000011018

Cheatham, H. (1990). Africentricity and career development of African-Americans. *The Career De-*

velopment Quarterly, 38, 334–346. doi:10.1002/j.2161-0045.1990.tb00223.x

Conrad, C. F., Neumann, A., Haworth, J. G., & Scott, P. (Eds.). (1993). *Qualitative research in higher education: Experiencing alternative perspectives and approaches.* Needham Heights, MA: Ginn Press.

Flowers, L. A., Milner, H. R., & Moore, J. L., III. (2003). Effects of locus of control on African American high school seniors' educational aspirations: Implications for preservice and inservice high school teachers and counselors. *The High School Journal, 87,* 39–50. doi:10.1353/hsj.2003.0014

Fouad, N., & Byars-Winston, A. (2005). Cultural context of career choice: Meta-analysis of race/ethnicity differences. *The Career Development Quarterly, 53,* 223–233. doi:10.1002/j.2161-0045.2005.tb00992.x

Gilbert, J. E., & Jackson, J. F. L. (2007). Introduction and state of the STEM world. In J. E. Gilbert & J. F. L. Jackson (Eds.), *M7 STEM white paper: Final report* (pp. 7–13). Milwaukee, WI: Marquette University.

Gilbert, J. E., Jackson, J. F. L., George, P. L., Charleston, L. J., & Daniels, B. D. (2007). SWOT analysis of STEM education: A study of the M7 region. In J. E. Gilbert & J. F. L. Jackson (Eds.), *M7 white paper: Final report* (pp. 38–66). Milwaukee, WI: Marquette University.

Glaser, B. G. (1999). The future of grounded theory. *Qualitative Health Research, 9,* 836–845. doi:10.1177/104973299129122199

Glaser, B. G., & Strauss, A. C. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Chicago, IL: Aldine Publishing.

Gottfredson, L. S. (2005). Using Gottfredson's theory of circumscription and compromise in career guidance and counseling. In S. D. Brown & R. W. Lent (Eds.), *Career development and counseling: Putting theory and research to work* (pp. 71–100). New York: Wiley.

Graham, L. P. (1997). *Profiles of persistence: A qualitative study of undergraduate women in engineering* (Unpublished doctoral dissertation). Virginia Polytechnic Institute and State University, Blacksburg, VA.

Guba, E. G., & Lincoln, Y. S. (1981). *Effective evaluation: Improving the usefulness of evaluation results through responsive and naturalistic approaches.* San Francisco, CA: Jossey-Bass.

Hrabowski, F. A., & Pearson, W., Jr. (1993). Recruiting and retaining talented African-American males in college science and engineering. *Journal of College Science Teaching, 22,* 234–238.

Jackson, J. F. L., Charleston, L. J., George, P. L., & Gilbert, J. E. (in press). Factors that attract African American males to computer science: A study of aspiring and current professionals. In M. C. Brown & T. E. Dancy (Eds.), *African American males and education: Examining the convergence of race and identity.* Charlotte, NC: Information Age.

Jackson, J. F. L., Gilbert, J. E., Charleston, L. J., & Gosha, K. (2009). Differential gender effects of a STEM-based intervention: An examination of the African American researchers in computing sciences program. In H. T. Frierson, W. Pearson, & J. H. Wyche (Eds.), *Programs, policy and academe as pertains to Black American males in higher education* (pp. 317–330). Bingley, UK: Emerald.

Jackson, L. A., Zhao, Y., Kolenic, A., III, Fitzgerald, H. E., Harold, R., & Von Eye, A. (2008). Race, gender, and information technology use: The new digital divide. *CyberPsychology & Behavior, 11,* 437–442. doi:10.1089/cpb.2007.0157

Jorgensen, D. L. (1989). *Participant observation: Methodology for human studies.* Newbury Park, CA: Sage.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry.* Newbury Park, CA: Sage.

MacLachlan, A. J. (2006). *Developing graduate students of color for the professoriate in science, technology, engineering and mathematics (STEM)* (Report No. CSHE.6.06). Berkeley, CA: University of California, Berkeley, Center for Studies in Higher Education.

Margolis, J., Estrella, R., Goode, J., Holme, J., & Nao, K. (2008). *Stuck in the shallow end: Education, race, and computing.* Cambridge, MA: MIT Press.

Margolis, J., Estrella, R., Holme, J. J., Goode, J., Nao, K., & Stumme, S. (2003). The computer science pipeline in urban high schools: Access to what? For whom? *IEEE Technology and Society Magazine, 22*(3), 12–19. doi:10.1109/MTAS.2003.1237467

Mason, J. (1996). *Qualitative research.* Newbury Park, CA: Sage.

Maton, K. I., Hrabowski, F. A., III. & Schmitt, C. L. (2000). African American college students excelling in the sciences: College and postcollege outcomes in the Meyerhoff scholars program. *Journal of Research in Science Teaching, 37,* 629–654. doi:10.1002/1098-2736(200009)37:7<629::AID-TEA2>3.0.CO;2-8

McAdoo, M. (1994). Equity: Has technology bridged the gap? *Electronic Learning, 13*(7), 24–34.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook.* Thousand Oaks, CA: Sage.

Moore, J. L. (2006). A qualitative investigation of African American males' career trajectory in engineering: Implications for teachers, school counselors, and parents. *Teachers College Record, 108,* 246–266. doi:10.1111/j.1467-9620.2006.00653.x

Parham, T., & Austin, N. (1994). Career development and African Americans: A contextual reappraisal using the nigrescence construct. *Journal of*

Vocational Behavior, 44, 139–154. doi:10.1006/jvbe.1994.1010

Pearson, T. (2002). Falling behind: A technology crisis facing minority students. *TechTrends, 46,* 15–20. doi:10.1007/BF02772070

Rudestam, K. E., & Newton, R. R. (1992). Surviving your dissertation: A comprehensive guide to content and process. London, UK: Sage.

Strauss, A. C., & Corbin, J. M. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Strauss, A. L. (1987). *Qualitative analysis for social scientists.* Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511557842

U.S. Census Bureau. (2008). *Annual estimates of the resident population by sex, race, and Hispanic origin for the United States: April 1, 2000 to July 1, 2008.* Retrieved from http://www.census.gov/popest/national/asrh/NC-EST2008-srh.html

Wolcott, H. F. (1990). *Writing up qualitative research.* Newbury Park, CA: Sage.

Appendix A

Study Participants

Status	%
Female undergraduate students	7
Male undergraduate students	15
Female graduate students (MS & PhD)	37
Male graduate students (MS & PhD)	11
Female professors/researchers	11
Male professors/researchers	19
Total	100

Note. All male and female professors/researchers hold PhDs.

Appendix B

Family Socioeconomic Status

Status	%
Low income, single head of household	18
Low income, dual-parent household	21
Middle income, single head of household	8
Middle income, dual-parent household	42
High income, single head of household	N/A
High income, dual-parent household	11
Total	100

Note. All percentages rounded to the nearest whole number.

(*Appendices continue*)

Appendix C

Gender Breakdown

Gender	%
Female	55
Male	45
Total	100

Appendix D

Educational/Occupation Status

Status	%
Undergraduate students	22
Graduate students (MS, PhD)	48
Professor/research scientist with PhD	30
Total	100

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