Exploring Factors Influencing the Continued Interest in a Computer Science Major

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Dr. Ryder became a Fellow of the ACM in 1998, and received the ACM SIGSOFT Influential Educator Award (2015), the Virginia AAUW Woman of Achievement Award (2014), and the ACM President's Award (2008). She received a Rutgers School of Arts and Sciences Computer Science Distinguished Alumni Award (2016), was named a CRA-W Distinguished Professor (2004), and was given the ACM SIGPLAN Distinguished Service Award (2001). Dr. Ryder led the Department of Computer Science team that tied nationally for 2nd place in the 2016 NCWIT NEXT Awards.She has been an active leader in ACM (e.g., Vice President 2010-2012, Secretary-Treasurer 2008-2010; ACM Council 2000-2008; General Chair, FCRC 2003; Chair ACM SIGPLAN (1995-97)). She serves currently as a Member of the Board of Directors of the Computer Research Association (2014-2020,1998-2001). Dr. Ryder is an editorial board member of ACM Transactions on Software Engineering Methodology and has served as an editorial board member of ACM Transactions on Programming Languages and Systems, IEEE Transactions on Software Engineering, Software: Practice and Experience, and Science of Computer Programming.

Dr. Ryder led the Department of Computer Science at Virginia Tech team that tied nationally for 2nd place in the 2016 NCWIT NEXT Awards. She was a founding member of the NCWIT VA/DC Aspirations in Computing Awards. Dr. Ryder has advised 16 Ph.D. and 3 M.S. students to completion of their theses; she has supervised the research of 4 postdocs and more than 30 undergraduate researchers at Rutgers and Virginia Tech.

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Exploring Factors Influencing the

Continued Interest in a Computer Science Major

Abstract: For this research paper, our study used a qualitative approach to better understand factors that impact the retention of students in computer science majors and minors at Virginia Tech, a large research university, and whether there were differences by gender. With increasing industry demand for graduates with computer science degrees, it is important for universities to identify methods for attracting and retaining students, particularly women, in computer science. Interactionalist theory which suggests student retention to a degree is based on personal and environmental factors provided the framework guiding our study. In addition, career certainty models allowed us to investigate how experiences at the undergraduate level influenced career interest in computer science. Questions included prompts to reflect on environmental and personal factors that sustained or diminished interest in continuing within a computer science degree and ultimately a career. Significant results suggest that females and males have a similar undergraduate experience and our results indicate that across institutions there are actionable steps that faculty members and graduate teaching assistants can take to positively influence career interest in computer science for undergraduates. Results also underscore steps that faculty can take to design educational approaches within their classrooms that would sustain interest in a computer science degree among both males and females.

Keywords: career interest, interactionalist theory, personal factors

Introduction

Recent trends point to increased interest in computer science as a career as colleges nationally are experiencing an increased number of enrollments in computer science courses and programs [1]. Institutions are not able to match the demands in student enrollment with increased faculty hires or even appropriate training on how to employ pedagogical approaches to teach in large classroom lecture formats [1].

At the same time, the field of computer science has been historically challenged by gender differences in the number of males and females pursuing computer science degrees and entering into computer science careers [2, 3]. According to a recent report by the National Science Foundation [4], women earn 57 percent of bachelor's degrees but only 18 percent of computer science degrees and women make up only 26 percent of the computing workforce. Trends in female representation in the computer science field have shown little improvement while the importance of the technology sector to the U.S. economy continues to increase [5].

In order to meet national workforce needs it is important to understand what factors influence a sustained interest in a computer science career [6]. To ensure a diverse workforce, research has shown that identifying factors specific to women is an important step toward changing the lack of female representation in the field [7]. Creating educational environments that facilitate career interest among undergraduate degree earners is an important step in the workforce pipeline [6, 7].

As a research team at Virginia Tech, a large research university in the southeast, we were interested in gaining a better understanding of both personal and environmental factors experienced by the students that were impacting student interest in a computer science major. The Department of Computer Science has experienced significant improvements in retention rates for males and females over the past few years, and therefore makes an interesting context to explore the experience the students were having. As a research team we were interested to know how students were experiencing the educational environment (i.e., environmental factors) and what personal attributes (i.e., personal factors) they felt were important for retention to degree and sustained interest in a computer science career. Doing so might help faculty and administrators better understand whether their efforts to facilitate retention to degree were reflected in the students' experience. The research question framing our exploratory investigation was: what personal and environmental factors impact students' interest in a computer science major and do those factors differ by gender?

Relevant Literature

Interactionalist theory [8, 9], the guiding framework for this study, suggests student retention to a degree is based on personal and environmental factors. Personal factors such as sense of belonging and whether students feel socially and academically integrated can influence whether students will remain in their chosen major and earn a degree [9]. The ways in which students experience the university organizational structure or other environmental factors also has been shown to impact retention [8, 9]. In addition, career certainty models allowed us to investigate how experiences at the undergraduate level influenced career interest in computer science [10, 11]. Personal factors such as motivation to persist towards a degree and feelings of competency in a given major are related to student degree attainment and likelihood to enter into a given career [11]. In addition, looking at how students experience the learning environment is important because environmental factors shape career outcomes [12].

Factors that Impact Progress in Computer Science

Research indicates that personal and environmental factors can shape initial interest in a computer science career. As students matriculate into their undergraduate degree programs these factors continue to facilitate or diminish a sustained interest. In some cases females are impacted differently by personal factors or experience educational environments in different ways than their male peers altering their continued interest in computer science.

Personal Factors

Personal factors such as motivation, sense of belonging, personal fulfillment, and identity can influence persistence to degree. Research shows that while these personal factors are unique to each student, educational environments can be structured or altered to influence some personal attributes in ways that positively impact retention.

Motivation can impact how students face and persevere through challenging concepts and course work. Research using project based computer game development has shown that assignments

can be structured to facilitate student motivation and encourage them to work through difficult material [13]. *Motivational factors linked to career choice* tend to differ across gender lines. Men tend to be more interested in money and prestige, compared to women who tend to value interacting with people, having a family, and work-life balance [14, 15, 16].

Other personal factors such as a *sense of belonging* and the degree of *personal fulfillment* that students receive from performance within computer science courses can influence their interest in computer science careers and retention to degree [17,18]. Sense of belonging has been shown to impact choice of major, grades, and interest in joining a company [3, 20]. For women, interacting with people who do not fit the male-dominated computer science stereotype can increase a woman's interest in the field, as can learning more about what computer science is and how it can be used [20, 21].

Identity compatibility, which considers how well an individual perceives their identity to align with a certain major or environment [3, 22] can also influence career interest. Identity compatibility can increase sense of belonging, decrease insecurity, and increase motivation, ultimately leading to retention within computer science [19, 22]. Gender is an important aspect of identity that is often in conflict for women in computer science [20]. In one study masculine traits were found to be stronger in female computer science majors than females in other majors [23], and computer science environments have been shown to be influenced by a culture that is heavily representative of males [3].

Self-efficacy is the expectation of success on a given task; women have repeatedly been shown to have lower computer self-efficacy than men [23,24]. This is true even when women have taken the same number of programming courses [24], have equal math skills, and even when they score better grades than men in computer science classes [23,24]. While a relationship has been identified between low social support and low self-efficacy in men, high social support did not improve self-efficacy for women [24].

A final personal factor that can influence persistence to degree and career choice is e*xposure to computer science as a career.* Being introduced to computer science concepts and what opportunities exist in computer science careers can help students make choices about majors and course work but also encourage their persistence to degree [15, 23]. In general, fewer women enter college with an interest in computer science or intent to take computer science classes [15, 23]. Men and women also differ in their reasons for being interested in computer science as a major. One study indicated that men develop interest through computer games, while women see computer science as a tool that can be used in a variety of fields [25]. Differences in how men and women are introduced to computers start at an early age, when men are often given computers to play with and women are not [21]. As a result, girls enter school with much less experience with computers than boys [21, 24]. Not only have they done less programming, but girls tend to have a less playful attitude toward computers, making them less likely to seek out careers in this area [21, 23].

Environmental Factors

In addition to personal factors impacting students' interest in computer science, there are several environmental factors present in higher education institutions and society as a whole. Pedagogical approaches, such as problem-based learning, interactions with faculty and peers, the physical environment, and access to role models can encourage persistence and retention.

A significant environmental factor in the university setting are the pedagogical methods used in classes. In *problem based learning* environments students have the opportunity to discuss concepts with peers and receive feedback as they work collaboratively on the open-ended problems. Research seems to suggest that this type of pedagogical approach provides positive opportunities for peer support as well as giving students the chance to clarify subject matter [26]. One study found that students in classroom environments that employ problem-based learning in introductory computer science courses had more positive perceptions about their learning, indicated they were more likely to have a positive attitude towards computer science, and were more likely to be retained in computer science majors [26]. While the immediate classroom environment and pedagogy employed has shown to influence student interest in computer science, other factors in the environment such as students' *interaction with faculty* and the quality of their *relationships with peers* also has shown to influence student interest in a computer science career [27, 28]. Receiving social support from peers can improve a woman's sense of belonging in computer science, decrease insecurity, and reduce her likelihood of changing to a different major [22]. Such support may be hard to find in computer science, where students are often competitive and a woman may be the only one in her class [21].

The *physical environment* present in a computer science department can affect a student's desire to join the field [3]. For example, one study indicated that collaborative spaces in a computer science department that might have a lot of posters or books that fit a stereotypical computer science major are a turn off to students whose personal identity does not align with those stereotypes. A perceived lack of alignment between the environment and a student's identity can significantly reduce his or her feeling of belonging in that environment [3, 20].

Outside of the immediate classroom environment, *parents and role models* can significantly impact decisions to join the field of computer science. Once girls are in the classroom, increasing the percentage of female teachers and professors of computer science can increase the percentages of female majors and graduates [7]. Similarly, interacting with male or female role models who do not fit traditional computer science stereotypes can increase women's interest in computer science [20].

Connections between Factors

Research has also shown that personal and environmental factors can also impact each other. Beyer and Haller [23] explored the connection between experience and self-efficacy, finding that the number of computer courses taken increases self-efficacy. Cheryan et al. considered how external environments interact with student identity [3], while London et al. looked at students' perceived compatibility between their identity and their major [22]. Identity was also tied to personal and professional values by Weisgram et al., who found that, regardless of gender,

people with masculine personality traits were more likely to have motivational career interests tied to power and money while those with feminine personality traits more often identified career interests tied to family [16].

Considering such connections between factors is essential in understanding how personal and environmental factors within a college setting interact to influence the professional identity of computer science students and whether there are differences by gender. Studies indicate that if computer science departments have a better understanding of why students select computer science as a major and what their experiences are like as they progress through their coursework, departments can implement interventions to positively address the matriculation rates of both male and female computer science majors [21].

Institutional Context

As a research team we were interested to know more about the experiences of currently enrolled computer science (CS) undergraduate majors at our institution, Virginia Tech. At the time this study was undertaken, the Department of Computer Science at Virginia Tech increased the percentage of female CS undergraduate majors from 4.2% in 2007 to 16.7% in 2015, and doubled the 2-year average percentage of female CS graduates since 2011 from 5.2% to 10.3%. The department also achieved retention rates in 2015 among undergraduates that are comparable for CS men (94.2%) and women (93.5%). The department has sought to incorporate best practices identified in the literature as having a positive impact on undergraduate enrollment and retention. Activities have included recruitment strategies such as holding open house and hands-on computer science focused events for middle and high school aged students, special welcome events for first year students interested in computer science, and workshops for high school teachers. The department has sought to diversify the faculty in order to bring in different role models for students, especially female faculty role models. Retention programs have also sought to address needs of currently enrolled undergraduates by building community through peer mentoring programs.

While the positive gains have occurred over time, data that can yield a better understanding of the students' experience has not been collected. In order to better understand the experience the male and female students were having in the CS department we were interested in exploring how they perceive the learning environment (i.e., environmental factors) and what they think are personal attributes (i.e., personal factors) that influence their interest in CS. With regard to institutional context, note that engineering students at Virginia Tech select their major at the end of the first year after completing a series of common first year engineering coursework.

Methodology

A basic qualitative research study design was used to answer the research question guiding this investigation [29, 30, 31]. We were interested in understanding the perceptions and experiences of the undergraduate students enrolled in the Department of CS as they pursued a computer science major. Interactionalist theory and career certainty models provided the conceptual framework for this investigation allowing us to seek to understand the students experience in the context of personal and environmental factors that may be influencing their interest in CS.

Merriam [31] notes that a basic qualitative research study is ideally suited to educational environments and helps create an understanding of how people interpret their experiences, how they construct their experience, and what meaning they assign to those experiences. Results of such a study can help educators identify programs, processes, or experiences that are effective [31].

A number of steps were taken to ensure the rigor of the study. The research team bracketed their prior assumptions and any experiences in the department as a student or faculty member to alleviate bias [29, 30]. The research team then designed an interview protocol that would allow students to describe their experiences and once data were collected the team moved into data analysis and interpretation. The development of the protocol and data analysis and interpretation procedures are described in detail below.

In order to understand the "what" and "how" of the students' sustained interest in the CS major a research protocol was designed to encourage students to reflect on and describe factors that sustained or diminished their interest in continuing within a CS degree and ultimately a career. For instance, we asked the students what initially interested them in pursuing a CS major and whether these same factors are motivating them to continue in the major. We also asked them what qualities someone needs to be successful in a CS major and whether they thought they had those skills. Questions asked students to consider what kind of career they saw themselves in and if it was CS related. Other prompts asked students to reflect on whether they felt prepared for a career in CS. In terms of the environment we asked students to describe the physical, academic and social environment in the CS department. We also asked students how they developed confidence and self-efficacy as it relates to CS related tasks. For a full list of the questions refer to Appendix A.

Following approval from the Institutional Review Board we sent an email to the 744 CS undergraduates inviting them to participate in a focus group in the Spring of 2016. Based on the positive responses to the initial email invitation and one follow-up reminder there were four focus groups held with a total of 25 students. Among those 19 were men, five women, and one student identified as "agender." Two of the groups were all male and two groups included both males and females. Of the participants, 19 were either fourth or fifth year students, while six of the students were in either their second or third year. Following the four focus groups another call for participation was emailed to students in the Fall of 2016. Due to scheduling conflicts and the inability to create a larger focus group, two students were scheduled in individual interviews. Individual interview participants included one male student and one female student. A third effort was made to collect data during the Spring of 2017 from students through an online survey that included the same questions as the interview protocol. A total of 20 students completed the open-ended survey items, nine males, 10 females, and one student that did not provide their gender. The protocol in Appendix A was used in the focus group, individual interviews, and the open-ended survey questions.

Focus groups and individual interviews were audio recorded and transcribed by a professional transcription service. The transcripts were first analyzed using an *a priori* coding process. Four broad categories served as the initial coding scheme including, personal and environmental factors influencing major and personal and environmental factors influencing career choices.

Participant experiences were coded within these four areas. Greater delineation in the codes were made as themes emerged. Each member of the research team coded the transcripts on their own and then compared the themes and codes that emerged. Differences in coding schemes were reconciled until the research team had a final set of codes so that rigor in the analysis was ensured. During this process the research team looked for differences in reported experiences between males and females. The open ended survey responses were then coded using this same process [29, 30]. As a final step in the analysis the themes and findings were shared with a sub set of participants as a means to ensure respondent validation.

Results

We categorized our results as dealing with either environmental or personal factors and present them in that order. Following is a table that summarizes the key themes and subthemes that were identified.

Table 1. Environmental and Personal Factors Influencing Computer Science Interest

Emergent Themes	Sub-Themes
Environmental	
Prior experiences	-Entry point through prior experiences before entering college encouraged a long term interest -Lack of access to prior experience led students to enroll in courses in their sophomore year, sometimes making students feel behind
Pedagogy and immediate educational environment	-Pedagogical approaches such as reliance on PowerPoint required students to be self-directed learners in order to sustain their interest -Approaches used by faculty such as modeling sustained interest
Culture of the computer science field	-Lack of previous knowledge and/or lack of faculty acknowledgement that subject matter was challenging left students feeling intimidated -Feeling prepared from a rigorous educational experience made students feel they could be successful in a CS career
Long term job prospects	-Lucrative job prospects encouraged an interest
Personal Factors	
Self-motivation	-Expectations set by faculty that students ought to be self-directed learners made participants feel that students need to be self-motivated in order to sustain interest -Students gained confidence and interest in CS by tinkering on non-graded assignments outside of class
Self-learning	-Willingness to engage in constant practice was important for sustained interest
Passion for computer science	-Having an innate passion allowed students to push through time intensive and challenging assignments, encouraging interest
Aptitude for computer science	-Participants noted an innate aptitude was necessary for continued interest due to challenging material

Environmental Factors

The data revealed four overall themes relating to environmental factors that impact both decisions to major in computer science and pursue a career in computer science. Themes included: a) prior experiences, b) pedagogy and immediate educational environment, c) culture of the computer science field, and d) long term job prospects. While the literature suggests that differences may exist between men's and women's experiences, such differences did not emerge in the data from our study with the exception of the value associated with and likelihood of participating in "tinkering" experiences.

The environmental factors influencing interest in computer science appear to start before students enter college. Participants were divided between those who had computer science experience before college and those who did not. Most of the participants in our study entered college knowing that they wanted to pursue a computer science major. Those who had past experience explained they developed their interest and understanding of computer science through video games and high school classes. This group of students felt that they knew what studying computer science would entail and had known for years that they wanted to study it. On the flip side, there were also students who explained that they entered college without having considered computer science at all. These students discussed the fact that their high schools did not have information technology or computer-based classes in it, they did not know anyone who worked in the field, and they had never tried programming before. In these cases, the students discovered the field of computer science by accident, typically by taking a class required for a different major. For example:

> *Personally, I came to [university] to be an electrical engineer, because I'm really good at abstraction. I took Intro to Media Computation just for fun, and then I really liked it, but then I thought I couldn't get a job in computer science. I talked to my advisor, and she's like, 'Yeah, there's actually like a field you can get a job in,' and it blew my mind. I've been really into it ever since.*

Choosing a CS major later in their sophomore year or later often required them to extend their stay in college or take heavy course loads in order to change majors. A common refrain among these students was that they wished computer science classes had been made available to everyone so that people could discover what it was sooner in their college career. One student suggested "*Everyone should be introduced to it, because a lot of people who aren't introduced to it probably had the aptitude, but they just didn't go for it*."

The second environmental theme that participants revealed related to the pedagogy used in computer science classes. In order to remain in a computer science major students explained that they needed to have the ability to learn things on their own, outside of the immediate classroom environment. Being a self-directed learner was important because participants explained that in their experience professors moved quickly through material, using PowerPoints as a primary tool to deliver course content. Students identified several issues with this format. First, they found it difficult to keep up with the professor as he/she moved through slides at a rate faster than students could take in the information. In this case, students found it more helpful to look at the slides later at their own pace. In a few instances students explained that the emphasis on

PowerPoints as the primary means to convey information made them feel as though the faculty members that relied on PowerPoints did not see teaching as a priority.

While participants identified challenges present in the learning environment, they also identified approaches that helped them learn. Faculty who could gauge when students were struggling with certain topics and slowed their pace in class were identified as very helpful. Likewise, faculty who modeled the approaches they expected students to use were identified as a helpful and students indicated that this was a pedagogical approach they would like all faculty to adopt. One commonly mentioned method was writing notes and examples on white boards, giving students a chance to think while the professor was writing. Another option was writing code along with students in class. In these cases, professors would project his/her screen for students to follow along as he/she made changes to code and demonstrated the results. Students particularly enjoyed when they were also invited to code in class and ask questions about the in-class programs. Multiple students suggested that a flipped classroom would be another good approach, although none had experienced it in their own classes. One student explained this idea:

> *I actually go to every class this year, just because, just to put myself in the learning environment, just to hear some stuff, but it's not really any different from when I didn't go to class and I just read all the stuff, because they just preach logic to you that, like straight from a slide or straight from a book, like the same thing, so why don't we just watch this lecture at home and then come to class with questions? Why don't we work on stuff in class? Where we're like sitting at home for hours, stuff that something that the teacher produced, like, 'Oh, we do this?' That would be so much more helpful to me.*

The third theme that emerged from the study participants was that the overall culture of computer science was intimidating. The word "intimidated" was used in answers to questions about professors and peers. Peers who had more programming experience were a key source of intimidation, especially early in the computer science program. There were a small number of professors who taught core classes that participants described as creating an intimidating atmosphere within their classrooms. This intimidation stemmed from professors referring to assignments as "easy" when they were struggling to complete them:

> *I think the condescension from professors is, it's not prevalent with everybody but there are just certain professors like they'll talk about assignments and they're like, 'This was a really easy assignment like you should know how to do this.' I think that's also a little bit frustrating when you're trying to learn this topic and if somebody is telling consistently that it's easy and you're struggling with it, it doesn't help you anymore to get it right, it just frustrates you more.*

Students noted that if they took advantage of office hours with faculty members the faculty took time to explain concepts to them they were struggling with,

> *Most of the faculty are friendly, even if they try to come off as intimidating in class. Although, I think they just try to be intimidating so that we take the class seriously. Office hours with most professors are always really helpful.*

While participants lamented the intimidating classroom environment they sometimes experienced, they did explain that their educational experience did make them feel prepared to tackle new and different situations. Participants explained that when they had the opportunity to apply what they learned in class, for example in summer internships, their confidence grew. Even if students felt intimidated by their classes, professors, or peers, a good internship experience showed them that they were more capable than they expected given the fact they were able to perform the tasks asked of them at their internships. One student compared herself to her co-workers:

> *I've had four internships, and I was doing really well in all of them, so I don't know. I feel prepared, because I was doing ... They'd give me tasks with a full-time worker, as a team, but then I'd be keeping at the same pace as the full-time worker. After my senior year, I would. Junior year, I couldn't, but last summer, I actually could keep pace with them, so I feel ready.*

The final environmental theme that emerged from the participants was that students remained in computer science because of the job prospects. Students of both genders discussed the importance of job security, being able to pay off their student loans, being able to support a family, and being able to make an excellent salary. Given their preparation during the undergraduate experience students felt that these things were attainable, "*… we have a great (undergraduate) program and the software industry is exploding. If you try your hardest, you can easily set yourself up for success, all the factors (job market, good program, salary, etc.) are in your favor*." Many participants referenced the fact that more industries are depending on computers, and recognized that the number of computer science jobs was going to increase in the future. Students also appreciated the fact that studying computer science would open doors to many different industries, describing the major as "flexible." Participants felt that they would be able to combine computer science with other interests or passions and make an impact on a variety of fields. Participants that entered into computer science because of video games explained how their views of the field expanded during their undergraduate study and helped them maintain interest in a computer science career. One participant explained,

> *I thought it would be cool to get into the video game industry but I think I've grown out of that. I feel like there's so much more I can do other than doing video games. I think it's just like I wanted, I feel like games have somewhat of an impact on people but there's other parts of the industry that can make more impact, at least personally for me other than video games. I just want to do something that will be beneficial to society at this point.*

Overall, lucrative job prospects were critical for maintaining student interest in the field of computer science.

Personal Factors

The data revealed four themes related to personal factors that influenced students' retention and interest in computer science as a career. These themes included: self-motivation, self-learning, passion for computer science, and aptitude for computer science.

Due to the expectations set by faculty that students ought to be self-directed learners, participants felt that students needed to be self-motivated. They explained that in order to learn computer science concepts, practice was key. One student noted,

> *By practice! Everything in CS takes practice to truly master. And if I am learning something for the first time, there are lots of external resources to help out. For example, when I started learning Java, I did the CodeAcademy tutorial online to help out.*

A self-motivation sub-theme that emerged distinct from practice was the idea of "tinkering," or carrying out personal computer science projects on their own time. Students who found time to work on projects that exercised computer science skills and knowledge outside of class assignments explained that it provided them with confidence. One student even felt that such projects were expected within computer science:

> *I think CS that feeling in general, I guess opposed to other fields, is you are more, I guess you are more expected to do work outside of class and like just learn like on the side as well as just doing I guess the core curriculum. Stuff like side projects and all that stuff is expected, whereas other maybe fields aren't...*

In our study, males were more likely to indicate they had multiple opportunities to tinker and were more likely to seek these experiences out than female participants.

A second theme that emerged in the data was the idea of "self-learning." Several participants emphasized that "self-learning" was a skill developed within computer science courses. For example:

> *I think getting thrown into the fire so many times has helped me. I had to self-learn or fail. You guys know what I'm talking about? That's helped me learn how to self-learn. I could self-learn; then I had a lifeline with the TAs….We definitely had to self-learn a lot of shell components, and it was nice because I could self-learn, and then I was stuck, I could go to the teaching assistant, and they'd help me out. Eventually, you could rely less and less on them.*

Willingness to immerse oneself in computer science was a distinguishing factor within the "self-learning" theme. Most participants concluded that there were two types of computer science majors: those who had interests outside of computer science and those who did not. Some found their peers who were solely focused on computer science intimidating, while others found them boring or one-dimensional. One student described these groups this way:

> *I guess I would divide them into two categories, and I think we kind of made those categories, but the people who do it just for a major…they don't pursue their own personal side projects, and it's like, come on. It's so easy to get started. Just read Google stuff, buy a book or something. Do some tutorials. Make your own little website or something just for fun, you know. Even though that's not necessarily programming, but then there are people who are really driven…and just tinker around and when you tinker, that's when you grow.*

Another student provided a different perspective:

> *I think another intimidating thing is the people who are super interested in CS, so much so that on a weekend, in their free time, they could think, it'd be really fun to learn a new programming language. They can just pick it up that weekend, and for me at least, it was intimidating that I don't really have that same kind of interest. Could I actually keep going with that since, to me, I like what I do in class, but have no interest to actually learn it on my own? History is my real interest, and with that I could, all my free time, read about something, like the American Revolution or something. I don't have that same interest for CS. I'm concerned about that. Now I feel like that's not a problem.*

A third theme that emerged from participant comments was that in order to study computer science, a student must have a passion for it and truly enjoy it. Otherwise, the students contended, a person would not be able to push through the hours it takes to find bugs in complex code. One student described it this way:

> *If you can find that passion for it, and it seems like it could click for somebody, then I'd definitely recommend it to them, because, at that point, if you're passionate about it, you'd probably want to do, you could do it, just because you find a reason for it. If it was just like some kid who just sits down and doesn't work all the time, uh, or is like average in school and doesn't really care too much about school or something like that. It's kind of hard to recommend it to them.*

Related to this, the focus groups also revealed that perseverance and patience are key to maintaining interest and self-motivation in field of computer science. Several participants used the word "stubborn" as a quality that someone needs to be successful in computer science. Participants unanimously agreed that being able to fight through difficult problems and continue to look for solutions was necessary in computer science. Similarly, the students felt that computer scientists cannot be afraid of failure and need to be able to learn from their mistakes and keep going. A participant described the struggle this way:

> *In CS you fail a lot, not like a test, but you will fail a lot and you will get very, very frustrated and you'll become very stressed at least that's from my viewpoint. It is job security, but some people just can't take that over and over and over failure, staying up very, very late to try and finish something and not getting anywhere. You could work for 5 hours on something and just not get anywhere. You even back track.*

One group discussed the fact that the need for patience and persistence was not acknowledged enough by professors. Faculty tended to focus on grading assignments and not necessarily providing feedback on the process or coaching students through challenging projects. Students explained that they had to develop an understanding that they were not the only person struggling with assignments and concepts. Therefore, peer support and interaction were important. One participant explained, "*They (peers) said just stick with it, stay with it. I think that's what helped me (stay in computer science)… because people are saying like, 'It'll get better*." Another student explained,

> *I'm not going to lie. The coursework is really, really hard, and so many times I have thought about quitting. A lot. I've spoken to a lot of other people, and a lot of other people feel that way, which kind of helps is that like, it's just really hard and when it's really new it just sometimes gets frustrating, showing up to every class and be like, "I don't know what you're saying!" You get used to it, but it takes a while to get used to it.*

Finally, many participants agreed that there exists an innate ability to do computer science. When asked if they would recommend computer science as a major to their friends, many students felt that only certain people would be able to be successful. The reasoning among participants was that only some people think in the correct way, have the right mindset, or have a high enough aptitude. One student put it this way:

> *If you don't have an aptitude, you'll just get burned out. The classes get so hard that if you don't have some sort of either aptitude for it or only take six credits at a time, you won't be able to finish the assignments. I saw that TAing just an intro course. Some people, they liked it, but they just weren't grasping things, and I wouldn't recommend majoring if it's going to be that frustrating, because you'll just get burned out and yeah, resent it.*

A minority of participants felt that anyone could learn if given enough time, but the majority maintained that computer science was an inherent skill.

Discussion

Our study was undertaken because we were interested to learn what experiences in the context of personal and environmental factors might facilitate a sustained interest in attaining a CS degree. Given the body of literature that suggests there might be differences by gender in these factors we examined whether males and females described different experiences. Our study identifies key personal and environmental factors that influence the interest of students in a computer science degree and career, regardless of gender. We were able to identify environmental factors that administrators and faculty can consider when they look to engage and retain students in computer science. Additionally the results of this study provide insight to personal factors including self-motivation and passion that students identified as necessary if undergraduates will successfully make their way through challenging and intimidating educational environments. The lack of differences in experiences that were described by both males and females may be a result of positive steps the department has taken to address the classroom climate. At the same time the common concerns expressed by the students identifies steps the department can take to continue to improve the experience for all students so they are retained to degree.

With regard to environmental factors, our findings confirm previous studies that suggest interest in a computer science degree starts with experiences that introduce students to the field through hands-on opportunities well before they might consider actual choice of major in college. These findings validate the need for camps, high school courses, or other activities that introduce middle and high school aged males and females to computer science. Students referenced specific outreach activities the department is already doing that led them to choose the

Department of Computer Science as their undergraduate major. Moreover, universities might want to consider exposing entering first year students to these same activities during a common first year experience before they choose a major. Participants indicated that having the chance to experience CS related content helped to encourage them to declare a CS major. If students had to switch majors and enter into CS they felt they were behind their peers, creating anxiety and frustration. Hands-on activities that allow them to begin to develop confidence and skills that lead them through challenging course work but also allow them to see the value that 'tinkering' on their own time yields appears to be a key component for sustained interest. Students indicated that experiencing the satisfaction of seeing something they created actually work was highly rewarding. The hands-on experiences might also allow males and females to become intrigued with computer science as a field as they experience these rewards early on.

In terms of personal factors, from the experiences relayed in the interviews and survey data it seems that if students lack a 'tough skin' and an interest in spending a great deal of time outside of class learning things on their own they may consider dropping a computer science major. This might be especially true for students who start off disadvantaged with lack of earlier prior experience experimenting with new approaches outside of an immediate classroom environment. Faculty and administrators might use this information to consider how to design classes and course material so that it is engaging and provides opportunities for the best practices students identified in their classes. Having instructors spend time working out problems, modeling solutions, and engaging in group discussion seems to aid student learning and engagement as they learn other students are struggling. Likewise, faculty could consider emphasizing how important it is for students to practice and persevere while also offering up time for office hours. Our findings show that hearing these things directly from faculty might encourage students to be retained. Ultimately, these things seem to sustain interest in the computer science major and field. Since males were more likely to cite opportunities to "tinker" on ungraded projects and described the positive benefits from getting to apply course material in a low stakes environment, departments may want to consider how to foster these opportunities for all students.

Our findings suggest that positive job prospects are not enough to encourage students to persevere to graduation. While students cited the positive flexible benefits of a computer science degree and endless job market they also explained students had to be passionate about the field. While passion is an innate personal factor, our findings suggest that if negative classroom experiences were diminished and students had an opportunity to engage in more positive learning that allowed them to see the many different ways computer science can be applied to solve problems their original passion might be sustained. In addition, our study indicates that if faculty take the time to acknowledge that there is material in class that all students struggle with and affirm the need for students to persevere, it might also encourage student retention towards degree.

Participants included males and females that were retained to their junior and senior year. All of the participants self-selected to participate and all of them anticipated graduating with a computer science degree. Future studies may look to conduct similar interviews with students that are exiting the computer science majors and moving to new fields of study. By gaining a better understanding of what factors sparked their original interest and what factors led them to leave computer science we would be able to address potential points of departure.

Conclusion

Examining personal and environmental factors that sustain an interest in computer science remains an important focus. By using a basic qualitative study design that was supported by rigorous methodological approaches we gained insights to the everyday experience of males and females that chose a computer science major and have been retained to their final years of study. As noted earlier this approach is well suited to educational environments and can yield information about the process and programmatic initiatives that are already in place or can be enhanced. This proved to be true with regard to the findings from our study. While the Department of CS at Virginia Tech has a number of initiatives underway to develop and improve student interest in a CS major and retention to degree, the results from this study can be used to shape the undergraduate experience of males and females to sustain interest long-term. The department has tangible and pragmatic initiatives it can implement such as addressing pedagogical approaches that allow for students to feel supported as they tackle challenging coursework. Results also identify promising practices already employed that can be expanded. For example, the department already has pre-college programs that expose students to computer science as a career. Based on students' experiences the department could also consider how to target the common first year engineering courses to expose students to computer science courses and career paths so students may choose the major sooner rather than switching majors. Moreover, these changes can be made to classrooms that will need to accommodate increased interest in enrollment in a computer science degree or training as enrollments are forecasted to increase. Administrators and faculty might consider how to conduct similar studies at their universities to determine if students' experiences are similar and what changes they can make to continue to see diverse groups enter the computer science profession. In summary, this study provides an example of how educational research can yield useful and informative data that departments can readily apply to programmatic initiatives.

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Appendix A

1. What got you interested in pursuing a CS major or minor?
2. What things do you like about your CS major? (classes, engagement with peers, interaction with faculty?) What other factors are motivating and encouraging you to stay in a CS major?
3. Are there any factors discouraging you from continuing in a CS major? Are there things you don’t like about your major? (class schedule, faculty/peer interactions…)
4. What are the biggest challenges you have faced in pursuing your CS major?
5. What kind of job or career do you see yourself in? CS related or not?
6. What qualities or skills do you think a CS major/minor needs to have to be successful? To what extent do you feel you possess these skills/qualities? [both academic (e.g., coding) and soft skills (e.g., communication)]
7. What are some things or experiences that have made you feel prepared to succeed in a CS major/minor? In a career?
8. What experiences do you still feel like you need to be successful in a CS career?

9. How would you describe the physical environment of the CS department – for instance, how you would describe a stereotypical classroom?
10. How would you describe the social environment of the CS department?
11. How would you describe the learning environment in your classes?