SUCCESSFUL FEMALE STUDENTS IN UNDERGRADUATE COMPUTER SCIENCE AND COMPUTER ENGINEERING: MOTIVATION, SELF-REGULATION, AND QUALITATIVE CHARACTERISTICS

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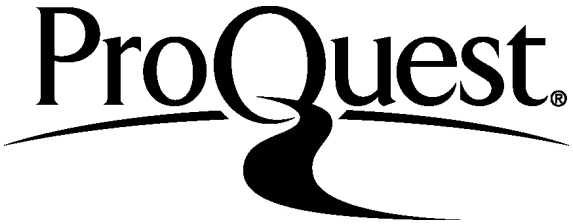

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University of Nebraska, 2016

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Computer Science (CS) and Computer Engineering (CE) fields typically have not been successful at recruiting or retaining women students. Research indicates several reasons for this shortage but mainly from three perspectives: social issues, exposure/prior knowledge and curriculum issues in K-12 settings. This mixed-methods research addresses a gap in the literature by investigating the motivation and self-regulation behaviors of successful female students who are studying computer science and computer engineering. The findings in phase one of this study indicated that learning and performance approach goals predicted adaptive strategic self-regulation behaviors including strategy use, knowledge building and engagement. Learning avoidance goals predicted lack of regulation. Task approach goals predicted knowledge building and engagement (each negatively) and task avoid goals predicted strategy use, knowledge building and engagement (each negatively). Engagement positively predicted course grades while lack of regulation negatively predicted course grades. Learning avoidance had a significant negative indirect effect on course grades through lack of regulation. Learning approach was associated with better regulation (i.e., lower lack of regulation) and higher grades. Performance approach had a significant positive indirect effect on course grades through

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engagement. Performance avoidance had a significant negative indirect effect on course grades through lack of regulation. Task avoidance had a significant negative indirect effect on course grades through engagement. Task approach, contrary to the hypothesized direct of effect, had a significant negative indirect effect on course grades through engagement.

Four themes emerged during the qualitative phase of this study. These included: The Gender Effect (students gender impacted their behavior and confidence), Lack of CS & CE experience (students' prior knowledge impacted how they studied and how competent they felt), Key Influences (students were influenced by the work and academic environment, family members, classmates and professors) and Problem Solvers (students responded to the rigor of the program by being aggressive problem solvers). This research has implications for how we can support other female students who have the potential or desire to excel in computing fields. K-12 school systems and undergraduate programs should take steps to create intentional programming that introduce, educate and help female students persist in computer science and computer engineering programs. Educators and parents should engage female students in math and science coursework and extracurricular activities early in life, especially where formal CS or CE programs do not exist.

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Table of Contents

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www.manaraa.com

www.manaraa.com

www.manaraa.com

List of Figures

www.manaraa.com

List of Tables

www.manaraa.com

List of Appendices

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Chapter 1

Introduction

There are not many people in the United States unaware that some science, technology, engineering and mathematics (STEM) fields are experiencing significant challenges in recruiting, educating, and retaining women, minority, and other underrepresented students such as first generation college students. This is evident by the onslaught of programs designed and implemented to engage girls and minority students in STEM such as, "Girls Who Code" and "Black Girls Code" (e.g., see girlswhocode.com & www.blackgirlscode.com). In the education literature, fields such as biology, chemistry, mechanical engineering and computer science, among others, are described as STEM fields of study. In fact, engineering and computer science domains appear to be most affected by shortages while math and sciences like biology and medicine seem to have stabilized (Cheryan, Plaut, Davies & Steele, 2009). As a result, research and public policy has focused on investigating and remedying this problem, with a particular focus on computer science and engineering but with the understanding that mathematics and scientific coursework are supportive of overall STEM success trajectories (Ehrenberg, 2010; Holdren & Lander, 2012). This general understanding is supported by several specific studies that underscore the need to understand ways in which students succeed in or drop out of STEM education areas (Li, Swaminathan, & Tang, 2009; Marra, Rodgers, Shen, & Bogue, 2012; Nelson, Shell, Husman Fishman, & Soh, 2015; Ohland et al., 2011).

Several research studies investigating this problem elucidate that success and challenges are context specific (Roberts, Kassianidou, & Irani, 2002). For example,

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STEM programs that have implemented specific strategies have shown significant increases in graduation rates (Roberts et al., 2002). Research also indicates that specific schools experience unique if not chronic challenges in STEM education areas, even in the areas where enrollment and retention has stabilized on average. For example, researchers found 42% of students at a large Midwestern university left the College of Science and Mathematics while only 30% of the original cohort completed the degree within a 4 to 6 year period (Koenig, Schen, Edwards & Bao, 2012). Other schools observed a similar trend. For example, a highly selective institution in the southern region of the United States reported that 21% of students who had initially enrolled in a STEM degree area did not graduate within six years. In the portion of students who did complete a degree, 15.5% of them changed their major to a non-STEM field of study such as The School of Management (Ackerman, Kanfer, & Beier, 2013). Context specific studies like these underscore the general fear that many developed nations have about the possible shortage of native-born skilled STEM workers (Burke & Mattis, 2007). The poor completion rate, as exemplified in these studies, of students in STEM fields has been linked to a shortage of sufficiently educated STEM teachers and proficient science and health professionals (Hutchison, 2012; Jones, Barlow, & Villarejo, 2010). The increasingly global nature of our economy along with the plethora of multinational issues, such as climate change, demand that we find ways to help students choose and excel in STEM fields.

Of particular concern to policy makers and educators are the stark success differences between males and females and between European American and non-European American students (Epstein, 2006; Gasiewski, Eagan, Garcia, Hurtado, &

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Chang, 2012; Wilson et al., 2012). The outlook for underrepresented minorities, particularly African American, Latino American and women students is especially alarming given the shortage of overall talent generally understood among STEM researchers and policy makers (Ackerman et al., 2013; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Knowles, 2013; Springer, Stanne, & Donovan, 1999). Goode (2008) asserts that, in general, the underrepresentation of females and students of color occurs at the K-12 level, the university level, and the professional level. These students tend to disproportionately enter and leave STEM education domains in comparison to male, White and Asian students (Berryman, 1983; Cook & Córdova, 2007; Myers & Pavel, 2011; Snyder & Hoffman, 2001). This exodus is explained in a number of ways. Goode (2008) points to lack of role models, curriculum that may not be culturally relevant and a shortage of pathways into STEM fields.

The rigorous nature of STEM education courses often impedes persistence when students in general are not prepared at the K-12 level (Li et al., 2009), but researchers have spent considerable time trying to explain why women students are disproportionately under-represented in STEM fields (Cohoon, 2001). Most explanations for this shortage are from three broad perspectives. First, there are important social issues that may limit participation. These types of issues could include feelings of isolation and exclusion, lack of STEM identity or problems related to stereotyping (Cheryan et al., 2009; Hernandez et al., 2013; Perez, Cromley, & Kaplan, 2014). For example, even girls who excel at math and science report lower self-confidence than boys (Burke & Mattis, 2007) in these domains. Some researchers suggest that girls tend to downplay their ability

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while boys feel more secure and comfortable in communicating their ability (Burke & Mattis, 2007). This outward display of ability could lead to boys receiving more encouragement and mentoring to engage in STEM fields than girls. Another related issue is science identity. Student's adoption of an identity congruent with STEM fields was correlated with positive beliefs about competence (Perez et al., 2014). In this way, students who felt a personal connection to a STEM field, feeling it was a part of who they are as a person, were more likely to excel. Researchers suggest that girls and other minority students tend not to develop strong STEM identities (Burke & Mattis, 2007). Scholars posit that females often battle being stereotyped by educators and peers or female students may come to believe stereotypes about themselves. For example, researchers examined 300 letters of recommendation to academic programs and found that female letters were shorter, contained more gender stereotypes (e.g., personality features like nice or easy to get along with) and mentioned more problematic aspects of the candidate, making them appear less favorable than their equally qualified male counterparts (Burke & Mattis, 2007).

Issues related to perceptions of ability and belonging could originate within underrepresented students as well. In stereotype threat research, scholars demonstrated how the mere environment of spaces in which STEM education was taking place deterred women and minorities when they were presented as overly 'geeky' and male (Cheryan et al., 2009). In the Cheryan et al. study, the authors found that simply changing the posters on the wall from a Star Trek theme to a more gender-neutral nature poster caused female students to feel more welcomed. Stereotype problems were also considered when

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researchers and STEM professionals examined media messaging about STEM fields. For example, Metz (2007) analyzed top education websites, ranked by search result order on Google's internet search engine that claimed to be a resource for people interested in STEM fields. She found that each website she viewed contained stereotypical and narrow definitions of what engineers do and tended to include images of White male students. For example, the websites tended to display White males at desks or looking at blueprints with other White males. She argues that the images promoted by media outlets and other members of the STEM community can serve as an effective barrier into the field. In effect, these narrow images do not help female students imagine working or studying STEM as a possibility in their personal future.

Another key issue that research discusses is the level of exposure and interest present for women and non-European-American students. For example, students may not be aware that STEM fields are viable options or they may not have been in situations that could enhance interest in STEM fields (Burke & Mattis, 2007; Buzzetto-More, Ukoha, & Rustagi, 2010; Knowles, 2013). Research has found that teachers or school counselors simply do not recruit some students to enter STEM fields, and others who have gained the skills and background knowledge necessary are not actively engaged in activities that could help cultivate interest in STEM (Burke & Mattis, 2007; Buzzetto-More et al., 2010). Still, another explanation is that parents are not actively pushing students in the direction of community and academic opportunities that would spark interest in STEM fields therefore some students lack exposure and encouragement from important support systems (Knowles, 2013). The general lack of information or inappropriate understanding

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of what STEM careers entail serve as barriers for talented students who would otherwise enjoy and benefit from a STEM education.

Finally, there are significant problems present in education contexts that stifle student success, such as poor general educational preparation, fewer skills needed to persist as course content becomes increasingly difficult, or limited access to specialized STEM teachers and curricula (Buzzetto-More et al., 2010; Gasiewski et al., 2012; Hambrusch, Hoffman, Korb, Haugan, & Hosking, 2009; Miller et al., 2013; Palma, 2001). In general, some K-12 schools and students have fewer educational tools that encourage teaching and studying STEM education in preparation to excel in those fields at the collegiate level (Burke & Mattis, 2007). Relatedly, Taasoobshirazi and Carr (2008) identified level of expertise at enrollment as why more women than men fail to persist in STEM areas. The researchers assert that women students sometimes begin introductory level courses without substantial preparation leading them to leave the field prematurely. Ackerman et al. (2013) suggested that gender differences in the proportion of AP STEM course enrollment impacts student retention once they enroll in college. Particularly, the completion of three or more AP STEM related tests correlates with STEM persistence. These researchers suggest that domain knowledge could be a significant contributing factor in predicting performance and persistence in STEM education fields, and gender differences in domain knowledge at college entrance are possibly related to differential STEM success (Ackerman et al., 2013). Given that the number of STEM high school courses taken by girls and boys is reportedly equal, the rigor of that coursework (AP

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placement, relative competitiveness between school districts) may be more of a deciding factor than enrollment in terms of adequate preparation (Ackerman et al., 2013).

The Present Study

This study used a two-phase mixed-methods approach in which I analyzed quantitative data about students' goals and study habits who has completed an introductory computer science course followed by conducting in-depth interviews with women students who explained their experiences and why they have been successful in the undergraduate computer science or computer engineering program. In this section, first I will clarify what computer science is and why it is important to study followed by the general state of the field for female students. Lastly, I will explain the approach I used to investigate this issue.

Computer science, defined as the study of computers and algorithmic processes, including their principles, their hardware and software designs, their application, and their impact on society, is a field integral to solving numerous problems (csta.acm.org). It can be harnessed to solve the problems people face in their daily lives, such as managing their time with digital calendars stored using cloud technology, or by using it to impact global issues such as the management of natural resources like fossil fuels or investigating climate change. Computer science is also a lucrative career and offers professionals flexibility within a field that demands a large workforce. Those skilled in computer science typically enjoy job security and the luxury of applying their skillset in diverse companies with varied missions. Computer scientists perform meaningful work

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that often conforms to personal preferences and therefore is a field that both men and women would benefit from entering.

Computer science, the study of the principles and use of computers, is widely considered a field within STEM education, representing multiple aspects of the acronym. For example, El-Kadi (1999) argues that computer science can be considered neither a science nor an engineering field as they are traditionally considered. Rather, computer science represents a new relationship between theory and experiments. El-Kadi continues by explaining that "computing professionals are concerned with the design and analysis of hardware and software to perform new functions or to perform old functions in a new way." Furthermore, computer science is representative of STEM fields because it requires the completion of advanced mathematics and science courses that are introduced in Kindergarten and presented in increasingly difficult curricula as students advance in K-12 schooling (Ashby, 2006). The fact that computer science includes an intersection of multiple aspects of science, technology, engineering and mathematics domains makes it a key example of a STEM field.

Computer science is a well-developed field at the graduate and undergraduate level, however K-12 education has not developed at a similar pace. As a result, some students are not exposed to computer science concepts prior to entering college and therefore begin undergraduate programs at an academic disadvantage. Many students (and adults) misunderstand computer science, not only because it is not as often taught in primary and secondary school, but also because it overlaps with the educational and information technology fields. Educational technology includes the application of

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computers to curriculum and the use of computer technology in educational settings and schools. For example, a teacher may use an interactive computer simulation to teach a complex science concept. Computer science, though, is concerned with the design, creation, testing, and verification of these educational tools. Information technology is also confused with computer science but this field deals with the use of software and computer hardware in the management of information systems. IT professionals install, customize, and integrate various programs and machines within organizations for optional information sharing, management, and security. Computer science, on the other hand, is concerned with the science and mathematics of these things, and seeks to design these tools and understand why they work. CS is therefore concerned with the design, development, and theory of computers and algorithmic processes (csta.acm.org).

Additionally, computer engineers specialize in software design, hardware design or systems designs that integrate both. Computer engineering is the marriage of computer science and electrical engineering. It is concerned with computing in all of its forms, including microprocessors, embedded computing devices, laptop and desktop systems and supercomputers. It is therefore concerned with the electrical functioning, design, and optimization of microprocessors and how data is communicated among those components. It is also concerned with how those electrical components process instructions expressed in software, how software is written, refined, and prepared for use in various hardware platforms (expert adapted from www. Lewisu.edu.). Computer engineering and computer science programs often share common courses and require students in both program tracks to complete them. This is because both work with data

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and work to derive meaning from it. As a results of this overlap, computer engineers and computer scientists often pursue similar careers and work on different aspect of the same projects (www.lewisu.edu).

Computing fields like computer science and computer engineering are a focus for study because they are experiencing problems in recruitment, engagement, and retention of underrepresented and female students. As a result, this study specifically uncovered how women students are able to excel in a field that is largely male dominated and contributed to the effort to increase the number of females who pursue and thrive in computing fields by offering research driven recommendations. In fact, how or why female students remain in STEM areas generally, and computer science specifically, is less studied than how or why students leave or never enter the field (see the synopsis of findings above). This 'deficit approach' is common across many domains and is often used when studying minority, remedial, or underrepresented groups (Harper, 2010). However, the present research employed an 'anti-deficit' approach to STEM education research that focuses on resilience and success in the context of an introductory computer science course. It aimed to uncover how female students are able to be successful in these courses *despite* the challenges that are well established by an extensive body of research on this subject (Cohoon, 2001; Harper, 2010; Roberts et al., 2002).

This research study examined female students who persisted in an introductory computer science course by investigating their self-described motivation and self-regulation and examining potential links to academic success and persistence. I analyzed data on certain motivational characteristics and self-regulatory behaviors of students that

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have been shown to have important positive outcomes in educational settings, such as higher grades, adaptive behavior in the face of challenges, sustainable study habits, promotion of knowledge development and retention, and positive views of ability (Schunk & Zimmerman, 2012).

This mixed-method study used quantitative methods to examine the relationship between goal orientation and strategic self-regulation and strategic self-regulation and success among female students in the course. Success was defined as obtaining a C grade or above. This grade was chosen both because of the small sample of female students and because it is typically the lowest course grade allowed to count toward a major or minor. This study also investigated the qualitative characteristics of female students who experienced success in the course using an instrumental case study design. According to Creswell (2007), case study research involves the study of an issue explored through one or more cases within a bounded system (i.e., a setting, a context). Consistent with Creswell's (2007) description, this study investigated the issue of successful female students in STEM within the bounded system of Computer Science and Computer Engineering. There are three quantitative research questions and one qualitative research question. *Quantitative Research question 1:* Was there a relationship between successful female students' goal orientations and strategic self-regulation? I predicted that learning and task goals would be associated with adaptive strategic self-regulation behaviors. *Quantitative Research question 2:* Was there a relationship between successful female student's strategic self-regulation and successful completion of the course? I hypothesized that female students who exhibit adaptive strategic self-regulation

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behaviors would be more successful in the course. *Quantitative Research Question 3:* For successful female student's, was the relationship between goal orientation and grades indirectly impacted by strategic self-regulation behaviors? I predicted that certain goal orientations are associated with certain strategic self-regulation behaviors which in turn impact course grades. *Qualitative Research question 1:* What were the characteristics of female students who successfully complete the course? I predicted that female students who have successfully completed the course will have been able to engage in positive self-regulation strategies and committed to adaptive goals during and prior to college, that helped them succeed in this rigorous academic atmosphere.

The relationship between these constructs and grades among female students studying STEM is less studied. Therefore, this research attempted to fill this gap in the literature and help identify the motivation, particularly goal orientation, and self-regulation characteristics among successful female students in undergraduate computer science and computer engineering courses. I predicted that successful female students adopted adaptive goal orientations which encourages positive self-regulation behaviors resulting in academic success. The findings generated by this work added depth to the research conversation concerning women in STEM by focusing on positive achievement and resiliency.

Recent research in this area has begun to focus on students with apparent aptitude for STEM education domains in an effort to challenge popular deficit hypotheses explaining the underrepresentation of women in STEM. For example, Carter (2006) queried several hundred high school students in Calculus and Pre-calculus classes to learn

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why more students with the apparent ability to excel in computer science chose another major. The researchers found that male students had considerably greater experience with computing than female students and, for both male and female students who did not choose Computer Science, the desire to avoid sitting in front of a computer all day was the top common deterrent. That research examined potentially high achievers at the high school level to try to uncover why students who could succeed in the field of study make choices against Computer Science while the present research examined characteristics of students who are currently succeeding in the domain. Riegle-Crumb, King, Grodsky, and Muller (2012) also doubt the prior achievement hypothesis and conducted research that examined "whether the comparative advantage that males and females possess in different subjects offers a more effective explanation of gender disparities at the postsecondary level." Using longitudinal data from a national sample, these researchers concluded that the achievement gap between males and females in mathematics and science was too narrow to explain the subsequent underrepresentation of women in STEM degree domains. Because advanced course enrollment differences between male and females did not fully explain the gender disparity, the authors suggested that future research should focus on other avenues, such as the study of gender as a social construct, to explain the disparity. Among other things, the authors suggest that researchers examine why and how some females resist cultural expectations and pursue degrees in STEM domains despite them. The present research contributed to the literature by examining successful female student's goal orientation and self-regulation and explored potential ways in which other students can be supported and prepared for similar outcomes.

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The context of the present research study is also important as phase one examined female students in introductory computer science courses. Data and analyses from this particular cohort will contribute to the literature in an important way because some introductory STEM courses tend to function as barriers to further pursuit of the field. For example, Roberts et al. (2002) assert that introductory courses were transformed into "filters" during the 1980's to decrease the number of students who would pursue and graduate with Computer Science degrees. According to the authors, this effort was a reaction to the inability of academic institutions to hire the appropriate faculty to meet the demands of enrollment. This practice hinges on the fact that those who experience poor performance in these introductory courses are likely to leave the field. The sample in the present research described the experiences of women students in a course that have historically been considered a filter or barrier class and may contribute to our understanding of this crucial timeframe. It is reasonable to assume that students frequently make decisions about pursing a major while experiencing the required introductory courses. These classes can indicate to students what they might expect from the major as they go forward. The qualitative phase of this study tried to uncover important, rich data describing aspects of what students come to understand about STEM education and how they cope with its rigor. Questions during this phase revealed the factors that contributed to success, general experiences before, during and after the courses, what support systems they relied on and their specific coping behaviors. Any other information that participants deemed necessary in terms of how they succeeded was included in the data collection process.

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Chapter 2

Literature Review

The present study examined characteristics of female students who excel in undergraduate STEM courses. The research about female students in STEM is exceptionally large and as a result the definitive characteristics of female students who excel academically is less clear. This challenge coupled with the fact that a large proportion of research about female students in STEM is conducted and reported from a deficit perspective (studying those that do not perform well or those who are at risk of being unsuccessful) warrants the necessity of examining those women who persist. This research provides the academic community with more detailed information regarding this population in an effort to enhance the likelihood that women's participation in STEM fields can be more thoughtfully supported. By describing the circumstances and characteristics that support women students who excel, steps can be taken to create environments and programs that may help other women excel.

Two constructs, motivation and self-regulation, were examined for their potential relationship with one another and their relationship to academic success in STEM coursework. Both goal orientation and self-regulation have been shown to be related to academic performance and persistence, which is of chief concern in this research, as well as a plethora of other outcomes relevant to college success. This literature review will examine both goal orientation (motivation) and self-regulation literatures separately and how they intersect. It concludes with an overview of how these constructs have been examined within female STEM student populations.

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Motivation Theory

Motivation is, in general, defined as the willingness or desire to engage in a specific activity. We often describe students as, for example, being motivated or not to complete their homework, give their attention to lecture, or work hard at tennis practice. We might describe someone with high motivation as being a self-starter and someone with low motivation as disengaged. Goal orientation, a motivation variable, has garnered considerable attention in academia in general and in educational research in particular. Its popularity is due to the fact that, within models of motivation, it can typically predict achievement or the lack thereof in various academic settings (Ames, 1992; Anderman & Maehr, 1994; Dweck & Elliott, 1983; Dweck & Leggett, 1988; Grant & Dweck, 2003; Kaplan & Maehr, 1999; Middleton & Midgely, 1997; Nicholls, 1984; Pintrich et al., 2000; Rawsthorne & Elliot, 1999; Schunk & Zimmerman, 2012). Goal orientation is a disposition toward developing or demonstrating ability and has previously shown the ability to predict knowledge development and retention (Bell & Kozlowski, 2002), the impact of feedback (Senko & Harackiewicz, 2005), and academic performance (Cellar et al., 2011). Goal orientation as it relates to achievement can be understood as one way that student's behavior is impacted "in terms of effort, persistence, choice, and performance" (Anderman & Midgley, 1997). A students' goal orientation can impact the decisions they make regarding a task; whether, for example, they choose to work hard or expend little or no effort. Therefore, goal orientation can inform several facets of human life, not limited to traditional educational settings (Cellar et al., 2011). However, studying what goals students set and the relationship of these goals to other behaviors, such as

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study behaviors and academic performance, can benefit teachers, students, and educational institutions as it relates to STEM fields of study.

Pioneered by Carol Dweck, John Nicholls and others, goal orientation theory was developed to answer questions about students' behavior, both adaptive and maladaptive, in achievement situations. The primary goal orientations described during early conceptions of the concept were mastery goals and performance goals. During that era, mastery goals were believed to derive from intrinsic motivation, i.e., for the love of the task or activity at hand and performance goals were believed to derive from extrinsic motivation, i.e., for some tangible reward such as a grades or money (Rawsthorne & Elliot, 1999). Though these two goals, mastery and performance, were largely the two goals studied in the original framework, there were various labels used by different researchers. For example, performance goals have also been referred to as ego-involved goals (Nicholls, 1984) and ability goals, (Ames, 1992; Butler, 1993), while mastery goals, learning goals and task goals are similarly defined (Dweck & Elliott, 1983; Nicholls, 1984).

Within this particular theoretical framework, these two goals have differential characteristics and consequences for a number of academic outcomes. As mentioned, students who adopt mastery goals are focused on learning the material for learning's sake, while students who adopt performance goals are more likely to be interested in demonstrating ability and besting peers. Mastery goals were considered superior in this dichotomy, leading to similar but greater educational outcomes than performance goals (Dweck, 1986; Nicholls, 1984). Furthermore, mastery goals were believed to stem from

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an overall belief that knowledge is malleable and therefore influenced by level of effort. On the other hand, those who adopt performance goals tend to approach knowledge as though it is fixed and less permeable by working harder (Dweck, 1986). These beliefs about knowledge are referred to as *implicit beliefs* and have been shown to be related to academic performance (Dweck & Leggitt, 1988). According to goal orientation theory, those with mastery goals should be more willing to engage in knowledge building efforts in various circumstances because knowledge is malleable, while those adopting performance goals may become stifled when met with challenges because of beliefs that knowledge and intelligence is fixed (Dweck, 1986; Dweck & Leggitt, 1988). In this way, beliefs about the nature of knowledge may be related to subsequent goal orientation.

Along with either a fixed or malleable mindset (Dweck, 2006), mastery and performance goals also define success differently. Mastery goals can be achieved by comparing performance with a task-criteria or self-defined criteria. This is often conceptualized as performance on a previous test, achieving a desired score or a feeling of accomplishment and improvement, respectively. Conversely, performance goal success requires outperforming peers due to a peer comparison conceptualization. Thus in theory it would typically be harder to reliably obtain success with performance goals than with mastery goals (Nicholls, 1984). This increased opportunity for potential success afforded to those who adopt mastery goals should lead to greater and more positive educational outcomes (Senko, Hulleman, & Harackiewicz, 2011). Performance goals, which are theoretically harder to achieve due to requiring the demonstration of ability, have been linked to feelings of helplessness after negative feedback. Those who believe

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their ability is already low are particularly vulnerable to debilitation via this process (Ames & Archer, 1988; Dweck & Elliott, 1983; Jagacinski & Nicholls, 1987; Meece, Blumenfeld, & Hoyle, 1988). Mastery goals are believed to have a different effect because the emphasis is on knowledge building and personal understanding and subsequently mastery goals were shown to facilitate persistence even when the belief of low ability exists (Ames & Archer, 1988; Butler, 1993; Elliott & Dweck, 1988; Utman, 1997). This early goal orientation model included only mastery and performance approach goals and therefore is sometimes referred to as the "dichotomous achievement goal model" and other, more complex models of goal orientation can be traced back to it (Elliott, Murayama, & Pekrun, 2011).

In the dichotomous model, both mastery and performance goals are formulated as *approach goals* (Ames, 1992; Nicholls, Patashnick, Cheung, Thorkildsen, & Lauer, 1989). Andy Elliott and his colleagues (eg., 2001) introduced an expanded model in the 1990's and 2000's that added *avoidance goals* to the goal orientation framework. In short, "approach motivation emphasizes seeking desirable outcomes, whereas avoidance motivation focuses on avoiding undesirable outcomes" (Huang, 2012). This expanded model is sometimes referred to as the "trichotomous achievement goal model" (Elliott & Harackiewicz, 1996) because the performance goal was separated into both performance – approach and performance – avoidance goals. Although research shows that mastery, performance – approach and performance – avoidance goals are most common; Elliot and his colleagues (Elliot, 1999; Elliot & McGregor, 2001; Elliott & Thrash, 2002; Fryer & Elliot, 2007) argue that some students adopt mastery-avoidance goals. As a result, Elliott

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introduced the 2x2 model in which the mastery goal was also conceptualized with an approach or avoid distinction (1999). Each goal in this model was theorized to have a specific set of consequences and antecedents (Elliott et al., 2011) and, in order to appropriately define the construct Elliott and his colleagues (2011) further argued that the definitional underpinnings of achievement goals needed to be revised. In his view, the construct should be defined by *competence* instead of *purpose*. Elliott et al. (2011) contended that 'purpose' carried two different definitions: (a) the reason for which something exists, and (b) an intended result; aim or outcome. Furthermore, Elliot and colleagues insisted that purpose was used within both of these contexts in research using the dichotomous framework causing construct confusion (Elliott, 2006; Elliot et al., 2011; Urdan & Mestas, 2006). Therefore, in the trichodomous and 2x2 models, achievement goals were defined in relation to aim (competence) solely (Elliott, 1999; Elliott & Fryer; 2008). According to Elliott et al. (2011), mastery-approach goals are geared toward achieving a task-based or self-based competence, mastery-avoidance goals focused on avoiding task-based or self-based incompetence, performance–approach goals are relative to other-based competence and performance–avoidance goals focus to other-based incompetence.

Elliott, his colleagues (2011) and others (Schraw, Horn, Thorndike-Christ, & Bruning, 1995; Shell & Husman, 2008; Shell & Soh, 2013) continue to work toward perfecting achievement goal theory and its conceptual model. Elliott et al. (2011) tested the possibility that achievement goals should be further delineated to include task-based, self-based and other-based aspects of the goals students set. Task-based goals focused on

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the task itself, with motivation related specifically to the demands of the task. Self-based goals focused on the personal trajectory and achievement is based on past performance and future possibilities for success. Other-based goals focus on comparison to those outside of the self and are normative in nature. Therefore, the 3X2 model included task-approach goals (complete the task correctly), task-avoidance goals (avoid completing the task incorrectly), self-approach goals (complete the task better than before), self-avoidance goals (avoid completing the task worse than before), other-approach goals (complete the task better than others), other-avoidance goals (avoid completing the tasks worse than others). Though this model is derived from the 2X2 model, Elliott et al. (2011) tested it against ten alternative models using confirmatory factor analysis and chi-square difference test to evaluate model fit and found evidence that the components of the 3X2 model are distinct.

Duane Shell and his colleagues (2010) expanded an alternative goal theory model drawn from earlier models (Dweck & Leggett, 1988; Schraw et al., 1995). This model was used in the present study. In this formulation, three dimensions are measured in terms of student's dispositions toward setting certain types of goals for class. They are: learning goals (i.e., mastery goals), performance goals, and task goals. Each goal has an approach and avoidance component and these are investigated relative to the classroom context (Ames, 1992; Elliott et al., 2011; Senko et al., 2011). Learning-avoid goals are defined here as student's desire to learn nothing as opposed to the Elliott et al. (2011) formulation that includes aiming to avoid doing worse than a prior experience. This divergence represents a difference in definitional approaches. According to Shell and Soh

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(2013), a student may complete all assignments satisfactorily however they may stop short of the effort necessary to actually learn the material. Some students may thus approach schooling as a series of tasks instead of a learning opportunity and therefore are likely to set learn-avoid goals for some classes (Bereiter & Scardamalia, 1989; Shell et al., 2010). Learning-approach goals are similar to prior formulations in that students who set them have the desire to gain new competence and knowledge (Dweck & Leggett, 1988; Senko et al., 2011; Shell & Soh, 2013). Performance – approach goals are also consistent with prior formulations (Senko et al., 2011) that describe the desire to demonstrate ability or perform better than peers. Task-or work-avoid goals are defined as a student's desire to put forth as little effort and time as possible while task–approach goals reflect the intention to complete assignments as best as possible but without any expectation for meaningful learning (Grant & Dweck, 2003; Shell & Soh, 2013).

Self-Regulation Theory

Researchers offer differing perspectives on what constitutes self-regulated learning and Zimmerman (1990) suggests that there are three theoretical perspectives from which self-regulation theories arise. First, operant theories argue that external stimuli influence self-regulation in the form of rewards, praise or social status whereas phenomenological theories contend that self-regulated behaviors are derived from the drive to reach self-actualization. Social – cognitive theories, on the other hand, emphasize the motivational aspects of self-regulation. In addition to these three perspectives described by Zimmerman (1990), there are also information processing theories that are grounded in what we have learned about brain functioning and concepts of memory as

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well as control theories that are grounded in similar cognitive processing theories (Carver & Scheier, 1982, 2001; Winne & Hadwin, 2008) .

Albert Bandura is credited with one of the earliest conceptualizations of self-regulation when he theorized about reciprocal determinism in the 1970's (Schraw, Crippen, & Hartley, 2006; Zimmerman, 1989). He argued that learning was derived from personal, environmental, and behavioral factors in what became known as "triadic reciprocity." This research sparked an interest in applying this model to educational settings. Subsequently, a robust body of research has emerged (Azevedo, Cromley, Winters, Moos, & Greene, 2005; Dignath & Buttner, 2008; Paris & Paris, 2001; Perry, Vandekamp, Mercer, & Nordby, 2002; Pressley, 1995; Ridley, Schutz, Glanz, & Weinstien, 1992; Schunk, 2008; Weinstien, Acee, & Jung, 2011; Zimmerman, 1990; 1998). In this tradition, Barry Zimmerman developed a cyclical (e.g. 1990) phase-type model of self-regulation. The Forethought phase includes task analysis and self-motivation beliefs. The Performance phase includes self-control and self-observation, while the Self-reflection phase includes self-judgment and self-reflection. This model is similar to the model presented earlier by Bandura that includes the self-observation phase, the self-judgments phase, and the self-reaction phase while Schmitz's model (2011) includes the pre-action phase that precedes learning, the action phase in which strategies are employed, and the post-action phase when students engage in metacognitive and affective reactions to the learning experience. Each of these phases influences the others, therefore self-regulation processes are cyclical and recursive in nature.

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Winne and Hadwin (2008) asserted that self-regulation is inherently constructed. These self-regulation processes involve cognitive and metacognitive strategies and include motivation and affective components. His work derives from a self-regulation framework that includes four stages. These include task definition, goal setting and planning, studying tactics, and adaptations to metacognition. In each phase, modes of information processing are influential. These influences are described as COPES; conditions, operations, products, evaluations, and standards. COPES are various types of information that students generate during a learning experience. Therefore, SRL is described in relation to the underlying processes in each phase. In Boekaerts' dual processing model, self-regulation consists of dynamic, interacting regulatory processes through which constant appraisals assign meaning to the learning activity as well as the three purposes for self- regulation (1997). She asserts that students engage in self-regulation to expand knowledge and skills, prevent threat to self, and to protect commitments. Carver and Scheier, on the other hand, proposed three processes underlying self-regulation in their self-control theory. These processes include goal setting, goal operating, and goal monitoring (2001).

Claire Weinstein and her colleagues (2011) have a slightly different conceptualization of SRL, as self-regulation is one facet of a larger theoretical framework. She used the term 'strategic learning' and defines the components as skill, will, and self-regulation. Skill includes knowledge about skills and how to use them in a particular domain, will regards motivation, goal setting and beliefs, and self-regulation includes time management, concentration, coping, and managing motivation. Conversely,

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Paul Pintrich (2000) put forth a taxonomy of SLR that includes phases and areas. The phases include planning, monitoring, effort to control and regulate, and reactions and reflections. The areas are cognitive, motivational/affect, behavior and context. Notice that this model includes context, while others exclude it because context includes a focus on controlling the environment outside of the person (Azevedo, et al., 2005). Perry and Rahim (2011) focus more closely on context and emphasize co-regulation and shared regulation. They assert that self-regulation can be co-regulated by teachers and peers and criticize other models that seem to treat individuals and contexts separately. They argue that especially within classroom contexts, self-regulation cannot be isolated from the context in which it takes place.

Although most of the models described here were developed with research that included older participants, the developmental nature of self-regulation is also studied in terms of the relationship between maturation and self-regulation abilities. Wigfield, Klauda, and Cambria juxtaposition Zimmerman's social cognitive self-regulation model with the corresponding developmental issues (2011). During the forethought stage language, goals, self-efficacy, competence perceptions, and task values of are importance. During the performance-monitoring phase, cognitive strategy use, delay of gratification, and persistence are fundamental while during the reaction and reflection phases, attribution for performance, affective reactions to performance and choices regarding future academic activities are important. As students age they are able to engage in these various processes through learning and more general cognitive maturity. The authors further assert that three key things develop that enable self-regulation.

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1. Capacity to regulate. Younger children have less mental capacity to regulate their actions and are influenced by biological limits.
2. Knowledge, strategies, and expertise develop in children and these developments can lead to differences among children's ability to regulate themselves.
3. Other factors related to self – regulation change such as the change in children's goals, the school years (e.g., 6th, 9th, grade, etc.) possibly driven by factors such as puberty and school building transitions.

Also, language use, affective reactions, and cognitive strategy use continue to develop and change over time. Therefore, "self-regulation is a result of changes in regulatory processes and factors influencing regulatory processes" (Zimmerman & Schunk, 2011).

As illustrated here, several models of SRL each include metacognition, cognition, and motivation and posit that individual's progress in their ability and willingness to engage in self-regulated learning with age and experience. The above summary of prominent SRL models and ideas about the development of self-regulation illustrate theoretical overlap as well as intricate differences among models. Next, I will discuss motivation studies that are instrumental to SRL.

Relevant Motivation and Self-Regulation Studies

Schunk and Zimmerman (2012) assert that motivation should be viewed as a collection of attributes about the self and tasks that can be regulated to their benefit. Stated differently, this perspective considers motivation as an attribute that needs to be regulated or controlled such that success is obtained. Hazley et al. (2014) studied goal

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change over the course of the semester. We found that most students come to class with positive goals, however, as the semester progresses, students adopt less optimal goals. Research studies that focus on motivation and self-regulation together tend to focus on how student's motivation impacts their use of SRL strategies (Pintrich, 2004). For example, Hazley et al. (2014) also found that student self-regulation and knowledge building were related to an increase in learning – approach goals and higher course grades were related to an increase in task-approach goal orientation. Conversely, an increase in task-avoid goal orientation was related to a decrease in SRL behaviors. In summary, students who increased positive goal orientations or decreased negative goal orientations increased in self-regulation strategies and experienced higher academic success. In another example, Pintrich & De Groot (1990) conducted a study that investigated the relationship between three motivational components and SRL. The researchers found that students' ability beliefs (entity/fixed versus incremental/growth), which are related to goal orientation, were closely related to SRL behaviors but these beliefs were not as closely tied to performance. The authors argue that both skill and will should be emphasized because each factor is less effective in isolation. Goal orientation is also more directly linked to SRL. For example, classrooms that promote mastery or learning goals have been associated with the use of self-regulatory strategies such as self-monitoring and evaluation more than climates that were considered to promote performance goals (Zimmerman & Schunk, 2011).

Additional research is being conducted by scholars such as Wolters (2011) is related to the perspective promoted by Schunk and Zimmerman (2011). However, this

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body of research seeks to understand how students regulate their motivation (Wolters, 1998, 1999). Researchers found that students engage in several specific activities as they regulate their motivation to engage in a task. For example, students might remind themselves of the performance goals they set, promise themselves an extrinsic reward, find ways to emphasize the tasks value, chose an optimal environment or alter it by playing desirable music, among other things (Wolters, 1999). This is interesting and potentially impactful because all students will likely experience failures, low desire to complete a homework assignment or otherwise encounter learning environments that are not ideal. The ways in which students stay focused on their goals and persist in spite of these challenges is an important way that SRL and motivation intersect.

Relatedly, research has found that goal orientation likely effects strategic self-regulation in impactful ways (Hazley et al., 2014; Wolters, Yu, & Pintrich, 1996). For example, Senko et al. (2011) conducted a meta-analysis and found that research shows that mastery goals facilitate learning in classes that require deep learning strategies. However, normative goals predicted grades while mastery goals did not. This illustrates the ongoing debate about the superiority of mastery goals over performance goals and how they impact strategic self-regulation strategies. Cellar et al. (2011) argue that mastery-approach goals should be correlated with self-regulation highly due to the positive emotions they invoke about learning while the negative emotions that are coupled with performance-avoid goals should not be correlated with self-regulation. Lynch (2010) studied the relationship between motivation and learning strategies and found elaboration, critical thinking, and metacognitive strategies to be linked to final

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grades more than rehearsal, organization, peers and help. In addition, Lynch (2010) reported that extrinsic goal orientation and critical thinking was correlated for females but not males. In fact, this scholar suggests that this research indicates that males and females may approach learning physics differently. In research conducted with high achieving students, Ee, Moore and Atputhasamy (2003) found that task-goal orientation and knowledge of self-regulated learning tended to have a positive effect on student's usage of SRL learning while work-avoidance goal orientation tended to have a negative impact on the usage of SRL. These authors assert that "goals affect motivation through their relationship with other variables rather than directly" (Ee et al., 2003). Less studied is how goal orientation impacts student's self-regulation in STEM populations among female populations. This research addressed our knowledge of this issue.

Interest, another motivational construct, has also been studied in terms of its effect on self-regulatory processes. For example, Zimmerman described a 4-phase progression of interest that leads to self-regulation. Phase 1 includes spontaneous interest, such as a chance exposure to a sport by a friend or neighbor. During phase 2 this interest is maintained, perhaps by the opportunity to participate in the activity. Phase 3 is engaged when the person chooses to continue participating in the activity without external prompts or support. And finally, during phase 4, the individual proactively engages in the activity such that a high level skill is developed, which is the phase that researchers assert include self-regulatory processes that aid in skill development and learning (Zimmerman & Schunk, 2011).

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In recent years, motivation is being considered as more integral to self-regulation theories and as a result scholars have devoted additional time toward investigating how, when, and why motivational constructs inform what we understand and still need to know about self-regulation. Su and Chen (2010), for example, found mastery goal orientation impacted students judgments of learning, a concept integral to self-regulation. Compared to performance goal oriented learners, those with mastery goals were better able to accurately predict what they understood and did so with more accuracy. Shell, Hazley, Soh, Ingraham, and Ramsay (2013) also found relationships between goal orientation and self-regulation. This research investigated the relationship between performance approach, performance avoid, learning approach, learning avoid, task approach and task avoid with four self-regulation behaviors. They were self-regulated strategy use, knowledge building, lack of regulation, study time and study effort. Performance approach was positively correlated with self-regulated strategy use, knowledge building and study effort but negatively correlated with lack of regulation. Learning approach was positively correlated with self-regulated strategy use and knowledge building but negatively correlated with lack of regulation. Learning avoid was positively correlated with lack of regulation and negatively correlated with self-regulated strategy use and knowledge building. Task approach was positively related to self-regulated strategy use, knowledge building and study time, while negatively correlated with lack of regulation. Task avoid was negatively correlated with all self-regulation behaviors except lack of regulation; there was no correlation with that variable.

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Several other motivational constructs such as emotion, self-efficacy, expectancy beliefs, intrinsic and extrinsic motivation, and others, are also studied in the context of SRL. Though beyond the scope of this review, these studies uncover relationships between these variables and self-regulated learning that likely impact our models of motivation (Zimmerman & Schunk, 2011). Some researchers, such as Shell and his colleagues (Nelson et al., 2015; Shell & Soh, 2013) assert that self-regulation should be studied alongside motivational constructs more deliberately. These scholars identified five profiles of motivated self-regulated students. They include: (a) a highly motivated "by –any-means" necessary, autonomous, strategy user; (b) intrinsically motivated and mastery-oriented student; (c) minimally engaged student who uses surface – learning strategies; (d) disengaged student who is apathetic; and (e) a motivated student unable to utilize effective strategies. These profiles illustrate the relationship between motivation variables and self-regulated learning behaviors and how these relationships correlate with adaptive or maladaptive behaviors (Shell & Husman 2008; Shell & Soh, 2013). Their profiles approach also demonstrates the need to consider students as 'whole' instead of focusing on fragmented parts of their behavior. This research can help us understand how motivation, self-regulation and other factors change or remain stable together. Nelson et al. (2015) extended the motivational and self-regulation profiles research by studying it in an introductory computer science class tailored for engineering students. In this research, the same profiles emerged. They found that 83% of the engineering students in the sample adopted maladaptive profiles which led to a lesser degree of learning than those who adopted other profiles. This research also suggests that students approach

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classes in their major differently than classes that are outside of their major or that they view as extraneous. For example, the researchers found that no students in the sample who were considering majoring in computer science, or who had already enrolled in that major, adopted the apathetic profile. This research illustrates the usefulness of studying self-regulation and motivation in specific domains, and seems to outline how especially useful it might be in the STEM context as researchers seek to understand its enrollment and retention challenges. Less studied is the direct relationship between goal orientation and self-regulation. Although Nelson et al. (2015) discovered profiles that suggest certain relationships between goals and self-regulated behaviors, the present research will directly test the relationship of goal orientation and self-regulation and how they might together impact performance. Additionally, while Shell et al. (2013) studied the relationship between goal orientation and self-regulation behaviors (described above), it does not study a high performing group of female participants. Indeed, the relationship between motivation and self-regulation is implied across several studies, but research questions directly addressing these relationships and specifically within a female student context are more limited.

Motivation and Self-Regulation in Female Populations

There is a growing body of research that investigates motivation and self-regulation that also includes research questions related specifically to female students, though the number of studies overall is quite small. For example, Zimmerman and Martinez-Pons (1990) cite research that studied gender differences in the use of 14 SRL strategies. Their findings indicated that females tended to employ more useful learning

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strategies than boys. Girls reported that they engaged in self-monitoring, setting goals and planning, and structuring the study environment more so than boys. Additionally, female students showed greater use of rehearsal, organization, metacognition, time management skills, elaboration and effort (Bidjerano, 2005). Rouse and Austin (2002) report findings showing that African American women who had higher GPA's also tended to have higher levels of motivation and self-concept beliefs when compared to African American men and African American women with lower GPA's. D'Lima, Winsler, and Kitsantas (2014) conducted research among first year undergraduate students and found that female students reported higher mastery goal orientations than male students and they were less performance-approach oriented than male students were. Female students also typically reported that they were less performance-avoid orientated than male students and, over time, male students tended to report decreased extrinsic motivation more than female students. Though male students were more performance-approach oriented than female students were, female students reported had higher GPA's as performance-approach goals were inversely related to grades.

In research conducted with minority students, including an African American sample that was 77% female, studying in STEM fields found that participation in research was linked to an increased slope for task goals, while it predicted a decrease in both performance–approach and performance–avoidance goals. In addition, the researchers found that increased tasks goals predicted increased academic performance while higher performance-avoidance goals predicted decreases in academic performance. Finally, this research indicated that performance–avoidance goals marginally predicted

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attrition from STEM (Hernandez et al., 2013). Female students were also, in a set of finding drawn from student in computer programming, shown to have slightly less motivation than males generally, but tended to report more intrinsic and less extrinsic motivation than male students (Doube & Lang, 2012).

Overall, the body of research that investigates motivation and self-regulation in female STEM populations is particularly small. However, there is a body of useful research that helps shed light on the characteristics of female students studying STEM more generally. For example, in research that tested the assertion that prior achievement is linked to the gender gaps in STEM, researchers found that prior achievement only minimally accounted for differential enrollment (Riegle-Crumb et al., 2012). The authors assert that these findings support prior research that found the gender gap in math achievement had fallen to one-tenth of a standard deviation thus further weakening the prior achievement argument in relation to STEM success disparities. These scholars suggested that future studies broaden the variables considered to impact the gender gap and include treating gender as a social construct and examining the institutional inequality and barriers that accompany it.

In qualitative research conducted by Varma (2010), students asserted that the gendered socialization and technical anxiety were the main contributors to the underrepresentation of women in Computer Science and Computer Engineering. Marra et al. (2012) conducted research to ascertain the reasons why engineering students chose to leave the field. Students indicated poor teaching and advising, difficulty level of the curriculum, and lack of belonging as the top three reasons they left the field. These

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reasons did not differ by gender. However, female students who left engineering had significantly higher cumulative GPA's than the males who also left the major. This is similar to the observation made by Felder, Felder, and Dietz (2002). These researchers found that female students showed higher levels of anxiety than male students despite being more motivated, better academically prepared, and proficient in better study skills.

Other research has investigated why high performing female students or students with apparent potential to succeed in computer science may choose other fields (Carter, 2006). The results indicated that male students were more likely to have experience in computer science. Males had, for example, taken at least one formal class at a higher rate than female students. Furthermore, when comparing males and females who had taken *more* than one formal class, results indicated rates of 13% for males and only 3% for females. Almost 80% of males had engaged in computer science related activities compared to 41% of females. Women actually reported experience in computer science as a deterrent to choosing the computer science major, whereas males indicated it was a positive factor in their decision to pursue it. Both men and women, however, agreed on the top three reasons that led to avoiding Computer Science; aversion to sitting in front of a computer for long periods of time, the previous decision to choose another major, and a desire to pursue more people – oriented fields of study. In fact, comfort level was shown to be a greater predictor of success in Computer Science than math (Wilson, 2002). Still, other researchers have studied STEM success by altering the time intervals within which graduation rates are examined. For example, Ohland et al. (2011) found that women engineering students graduate in six years as opposed to four years at higher rates than

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men at six of the nine institutions in the sample and the gender gap at five of the nine institutions was smaller than 5%. When the gender gap was larger, it favored women and occurred at the institutions that graduated women at higher rates.

Overall, these studies highlight the need for research that investigates the role that motivation and self-regulation play in STEM success specifically and in the female student context particularly. My literature review clearly indicated that there is a limited body of research that specifically examines and/or models these variables and potential processes in a female STEM context. Another example that illustrates this gap, is a literature review conducted by Kondrick (2003). This research investigated research about women's persistence toward STEM career goals. A wide range of theoretical frameworks were used such as coping theories, feminist perspective theories, theories about the impact of race, economic status, exposure to STEM and emotions. However, none of the research investigated the impact of motivation or self-regulation on academic success. Furthermore, most research reviewed here considers female students in STEM majors from a deficit perspective. Rarely do researchers study the students who were successful despite the barriers that we generally understand to be an obstacle for women students. The present research addressed these gaps by investigating the motivation and self-regulatory characteristics of successful female students in a STEM education context. This research can help policy makers and educators understand the ways in which motivation and self-regulation influence female student's academic success in STEM fields.

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The Present Research

This review of the literature illustrates that most research to date has not studied self-regulated learning or goal orientation within female populations in STEM majors who are succeeding. The research I conducted helps describe the potential relationship between goal orientation and self-regulated learning and self-regulated learning and course grades. This study also investigated the qualitative characteristics of female students who complete STEM education classes successfully and presented information critical to designing supportive programs for other students. My research was conducted with students who took an introductory computer science (phase one) course and those enrolled in a computer science or computer engineering program (phase two) at a large Midwestern university. Students in this sample have majors other than computer science as the introductory computer science courses were offered in a suite, each tailored to students with different majors. My research questions focused on the motivation, self-regulation and qualitative characteristics of female students who have completed a computer science class with a C grade or better. I chose grade C because it is the cut-off for major and minor qualifying courses at the University in which the sample is drawn. In addition, grades of C- and below do not qualify toward most majors or minors.

Female STEM students. As previous research indicates, I expected female students to be enrolled at a lower rate than male students in the computer science courses (Berryman, 1983; Cook & Córdova, 2007; Myers & Pavel, 2011; Snyder & Hoffman, 2001). I also expected female students to exhibit a range of goal orientations and self-regulatory behaviors. Consistent with prior research, I also hypothesized that female

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students who completed the course is this study successfully would be more likely to adopt and report adaptive goal orientations and engage in positive self-regulated learning strategies (Bell & Kozlowski, 2002; Cellar et al., 2011; D'Lima et al., 2014; Hazley et al, 2014). Prior research suggests that females tend to adopt more beneficial self-regulated learning strategies than males, and I expected the findings in this research to reflect similar patterns (Zimmerman & Martinez-Pons, 1990). Furthermore, I hypothesized that the qualitative data would indicate that successful female students exhibit advantageous characteristics that prime them for success. I expected female students who both completed the STEM course and performed well academically to have had prior STEM or math experience, demonstrate the ability to navigate campus resources to their advantage, and have positive social support systems (Marra, et al., 2012; Varma, 2010).

Quantitative and qualitative methods. Students in the current study have participated in pre- and post-tests that assessed their goal orientation and self-regulation behaviors. The instruments are self-report questionnaires that asked students to think about their goals for the course and to describe their self-regulation behaviors over time. Goals are operationalized here in three dimensions: learning, performance, and task as consistent with the model proposed by Shell et al. (2010) and Shell and Soh (2013). Each dimension has an approach and avoid aspect. The instrument utilized in this study was also used by Shell et al. (2013) and adapted from that used by Shell and Soh (2013). Strategic self-regulated learning is operationalized here as including four dimensions or behaviors: self-regulated strategy use, knowledge building, lack of regulation and engagement as defined by Nelson et al. (2015). This research employed the Student

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Perceptions of Classroom Knowledge Building Instrument (Shell & Soh, 2013). While these assessments could be conducted in real time (e.g., immediately before or after an assignment) this design provides the opportunity for students to judge their actions over time and therefore consider a range of possible assignments or tasks which to apply the questions. Though such questionnaires have been criticized due to the possibility that some students are not accurate judges of their behaviors over time or their future intentions, similar assessments have been widely used in scholarly research and viewed as a viable way to measure these latent constructs (Zimmerman & Schunk, 2011). Also, the qualitative data was used to compliment the quantitative data by synthesizing the qualitative and quantitative findings.

The qualitative phase of this study included conducting interviews with female students who had successfully completed computer science courses and were in good academic standing. An interview protocol that I developed asked specific questions in four categories: prior STEM and math experience; career aspirations; support systems and; coping behaviors. Students were asked about their experiences in other STEM type courses and mathematics because research suggests that these experiences are supportive of success in collegiate level STEM education (Riegle-Crumb et al., 2012). Student's career aspirations were assessed because prior research indicates that STEM careers can be viewed as overly masculine or geeky (Cheryan et al., 2009). This is often considered a deterrent to pursuing STEM majors and careers. Support systems were investigated because it is considered another area that female students find challenging (Knowles, 2013). Because of the low numbers of female students in STEM education, research

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suggests that the isolating atmosphere can interfere with female student's ability to be successful. Lastly, students were asked about their coping strategies. Because of the low number of female students who enroll and complete STEM degrees, it would be beneficial to understand ways in which these students were are able to cope. All of the questions were open–ended and students were allowed to guide the conversation. The interviews were guided and exploratory in nature as students were allowed to steer the conversation (Creswell, 1998, 2013).

Primary research questions and hypotheses. The main objective of this study was to examine the association between goal orientation, strategic self-regulated learning and student's grades. I examined the relationship between goal orientation and strategic self-regulated learning and strategic self-regulated learning and grades in computer science courses. Prior research suggests that motivation, including goal orientation, and self-regulated learning are intricately related (Anderman & Midgley, 1997; Carver & Scheier, 2001; Pintrich & De Groot, 1990; Senko et al., 2011; Winn & Hadwin, 2008). This study tested that relationship. Importantly, this study maintained a major focus on the characteristics of those female students who completed courses successfully. Previous studies have largely investigated why female students leave or never enter the field (Marra et al., 2012; Riegle-Crumb et al., 2012; Varma, 2010). Less studied are the female students who persist. Therefore, female students who successfully completed courses with a grade C or above were invited to participate in an interview.

Research question 1 (quantitative). What was the relationship between students' goal orientation and strategic self-regulated learning behaviors?

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Specifically, the relationship between learning approach and avoid, performance approach and avoid and task approach and avoid goal orientation and four strategic self-regulation behaviors including: (a) strategy use, (b) knowledge building, (c) lack of regulation, and (d) engagement were tested. Given the research about goal orientation, I hypothesized that learning and task goals will be associated with adaptive strategic self-regulated learning behaviors (Hazley, et al., 2014; Senko et al., 2011; Zimmerman & Schunk, 2011). Though there is little research to suggest this specific relationship, research on goal orientation in general indicates that adaptive goal orientations are associated with SRL and academic success (Hazley, et al., 2014). This seems to indicate that successful students engage in behaviors that promote learning and retention (Cellar et al., 2011).

Due to sample size limitations, follow-up (post hoc) analyses were conducted to examine whether or not successful female students displayed higher levels of the adaptive goal orientations and self-regulatory behavior patterns, as compared to groups of males and/or successful male students.

Research question 2 (quantitative). What was the relationship between strategic self-regulated learning behaviors and grades in the course?

Prior research suggests that students who exhibit positive strategic self-regulation behaviors will be more successful in college courses (Hazley, et al., 2014; Shell & Husman, 2008; Shell & Soh, 2013). I hypothesized that similar patterns of associations will emerge in this research. Students who are successful in the class will likely display higher levels of adaptive strategy use as described by Pressley, Borkowski, and Schneider

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(1987). The sample size necessitated that follow up (post hoc) tests be conducted to examine the relationship among the variables for female students.

Research question 3 (quantitative). Was the relationship between goal orientation and grades mediated by self-regulation behaviors? I predicted that certain goal orientations have a stronger relationship with certain strategic self-regulation behaviors, which in turn impact course grades. Although this relationship is rarely tested in the literature, many studies suggest strategic self-regulation mediates the relationship between goal orientation and outcomes such as grades (Hazley, et al., 2014; Shell & Husman, 2008; Wolters & Rosenthal, 2000). I also examined whether or not these patterns differed by gender (see post hoc tests described above).

Each of these three research questions were tested in a single model using Structural Equation Modeling illustrated in Figure 1. Each Goal Orientation was tested for its relationship to four different strategic self-regulated learning behaviors, illustrated below and described above. Also, this model tested the relationship between strategic self-regulated learning and course grades.

Research question 4 (qualitative). What were the positive, adaptive strategy use and goal setting characteristics of female students who successfully complete the STEM education course?

Prior research involving female students in STEM education programs suggest that they face challenges such as isolation, low exposure to STEM fields prior to college and an inability to cope with the gender-related stressors within a male dominated domain (Ackerman et al., 2013). Goal orientation and self-regulation behaviors are less

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studied. I hypothesized that female students who have successfully completed STEM courses were able to engage in positive strategies and commit to adaptive goals during and prior to college that help them succeed in this academic environment.

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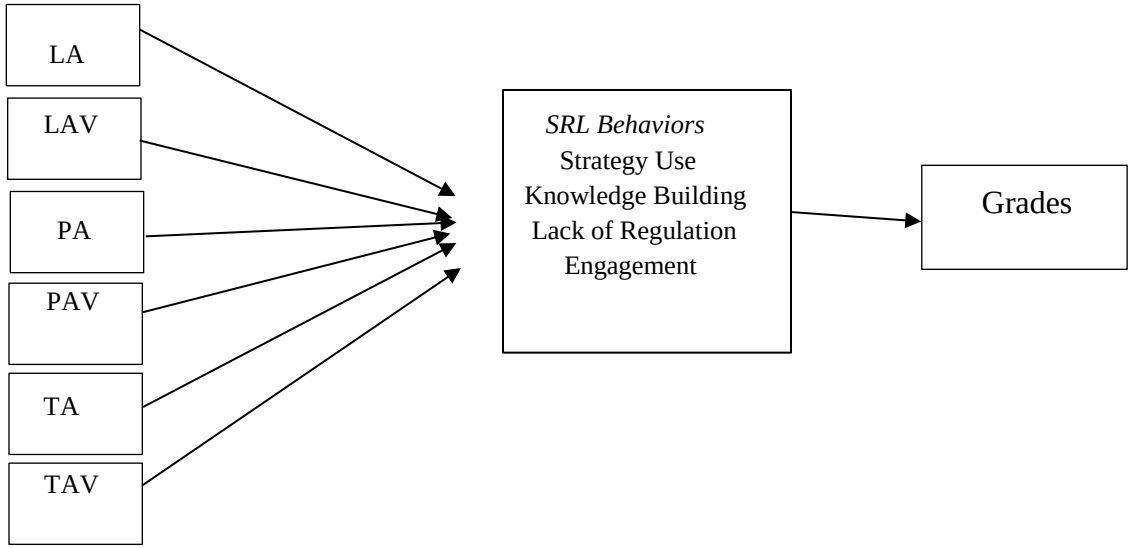

Figure 1. Theoretically derived SEM model of goals, SRL and grades.
Note. Using Structural Equation Modeling, this figure illustrates the hypothesized relationship between Goal Orientation and 4 Strategic Self-Regulated Learning (SRL) Behaviors and SRL behaviors and grades. This model also proposes SRL's mediating-type relationship between Goal Orientation and Grades. LA=learning approach. LAV= Learning avoid. PA= Performance approach (normative). PAV= Performance-avoid. TA=Task approach. TAV= Task-avoid. The mediating role for each of the four SRL behaviors will be evaluated using separate model.

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Chapter 3

Methodology and Data Analysis

This study employed a complimentary sequential mixed-methods design (Creswell, 2013; Creswell & Plano Clark, 2010) and used the qualitative component to provide an extra dimension that describes the characteristics of female students studying in STEM majors by using the case study method. In an instrumental case study, the researcher focuses on a pertinent issue, such as shortage of female students, and then selects one bounded case, such as computer science and computer engineering, to illustrate the issue (Creswell, 2007).

Phase one included the quantitative phase and phase two included the qualitative phase. The quantitative phase occurred first and was analyzed using structural equation modeling. The data from the qualitative phase, collected second, was analyzed and coded to uncover common themes using qualitative research methods defined by Creswell and Plano Clark (2010). Next, the qualitative and quantitative data were synthesized to explain how the data complement each other.

Quantitative Phase

Participants & procedures. I conducted this study as a secondary data analysis as participants in phase one of this two-phase complimentary sequential mixed-methods study were drawn from a larger, National Science Foundation-funded effort to improve undergraduate computer science courses at a large Midwestern state university. Student participation was on a volunteer basis and only students who consented to the use of their grades in the initial data collection phase were eligible to participate in the data analysis phase of the study. Course grades were obtained from University records. A pre-survey

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was administered during the first week of classes and a post-survey was administered one week before final examinations. Data were electronically collected in class. Courses were offered in a suite with each tailored to a specific major, therefore grades were transformed across the courses using z-score transformation. Additionally, the participants in this study were not limited to computer science and computer engineering students due to the low number of females in computing fields. Instead, STEM students who completed the introductory CS course and elected those majors were included in the quantitative phase of this study. The data were collected during Fall 2012, Spring 2013, Fall 2013, Fall 2014 and Spring 2015. The list of the most numerous majors in the sample are in Appendix F. The courses from the suite that were included in the sample were CS1 – Computer Science, CS1- Engineering, CS1- Mixed, and CS1 - Honors. CS1- Computer Science was designed for computer science majors who could enroll either through the College of Arts and Sciences or through the College of Engineering. The CS1-Engineering course was designated for students who were non-computer science engineering students (mechanical, engineering, civil engineering, electrical engineering, etc.). The CS1- Mixed course was for computer science, business, and general science major students who preferred the (C++) programming language. The CS1 – Honors course was designed for students majoring in the combined computer science and business degree major. During the Fall 2014 and Spring 2015 semesters, additional courses were included in the larger NSF study and those classes are listed in Appendix F.

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I analyzed the descriptive statistics to quantify and isolate the number of students in the total dataset that were STEM students. I also examined the number of males and female participants as well as the number of freshmen, sophomores, juniors, and seniors.

The race and ethnicity of the students in this study were not collected due to concerns about indirect identification of minority students. Because there are so few minority students, this precaution was deemed necessary by the principle investigators and the institutional review board. However, because the CS courses are required, they would reflect the demographic representation of the college and majors represented. During the timeframe that these data were collected, college records indicate that engineering majors were 92% European American, 2% African American, 3% Asian, 3% Hispanic, 4% International Students; computer science majors were 87% European American, 2% African American, 6% Asian, 5% Hispanic, 7% International Students; the combined computer science honors program were 89% European American, 0% African American, 9% Asian, 2% Hispanic, 0% International Students; general business and other science majors were 77% European American, 2% African American, 2% Asian, 3% Hispanic, and 17% were International Students.

Measures.

Motivation. Student's motivation was measured using the goal orientation instrument utilized in Shell and Soh (2013), Shell et al. (2013), and Nelson et al. (2015). This instrument was adapted from the goal orientation instrument developed by Shell and Husman (2008) which was based on the goal framework described in Shell et al. (2010). Three dimensions were measured: learning, performance, and task.

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Learning goal orientation. The learning approach scale assesses goals for pursuit of long-term, deep understanding of the course content. There were (3) items included in this scale with that assessed goals for deep learning and long-term retention of knowledge (e.g., "…really understanding the class material").

Learning avoid goal orientation. Learning avoid goal orientation (3) includes items that assess deliberate goals to avoid any meaningful learning (e.g., "…learning enough to get through the test after which I can forget about it").

Performance approach orientation. Performance approach orientation (3) assesses performance relative to other people, or normatively (e.g., "…getting the highest grade in the class").

Performance-avoid goal orientation. Performance-avoid goal orientation (3) measures goals to avoid being viewed negatively relative to performance and ability (e.g., "…not looking stupid").

Task-approach goal orientation. Task-approach goal orientation (3) assesses goals to perform well in the class without a normative focus (e.g., "…getting a high grade on tests and other assignments").

Task-avoid goal orientation. Task-avoid goal orientation (3) assesses intentional goals to expend as little effort as possible in the course (e.g., "…getting a passing grade with as little studying as possible").

Participants rated goals on a 5-point Likert scale from 1 (very unimportant) to 5 (very important). Scores were calculated as the mean score of the items in each scale. Cronbach's alpha reliability estimates for the learning approach, learning avoid,

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performance approach, performance avoid, task approach, and task avoid scales were .87, .86, .79, .85, .90, and .81, respectively. Additional instrument validation information is available in Shell and Husman (2008) and Shell and Soh (2013).

Strategic self-regulation. Self-regulation was assessed using the Student Perceptions of Classroom Knowledge Building Scale (Shell et al., 2005). There were six focus areas. *General Self-regulation or Strategy Use* (5 items) assessed participants planning, goal setting, monitoring, and evaluation of studying and learning (e.g., "…In this class, I tried to monitor my progress when I studied"). *Knowledge building* (5 items) assessed student exploration and interconnection of knowledge from the class (e.g., "…As I studied the topics in this class, I tried to think about how they related to the topics I have studies in other classes"). *Engagement* consisted of 2 scales. *High Level question asking* (3 items) includes items that assess the extent to which students ask questions that go beyond basic understanding (e.g., "…In this class I asked questions that interested me"). *Low-level Question asking* (3 items) assessed the extent to which students asked questions that did not extend basic understanding of course material (e.g., "…In this class, I asked questions so that I could find out what information the instructor thought was important"). *Lack of regulation* (4 items) assessed participants' lack of understanding of how to study and the need for assistance and guidance in studying (e.g., "…In this class, when I got stuck or confused about my work, I needed someone else to figure out what I needed to do"). The high and low level question asking scales were combined in my analysis.

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Participants answered questions on a five-point Likert scale from 1 (almost never) to 5 (almost always). Scores were computed as the mean score of the scale items. Cronbach's alpha reliability estimates for the self-regulated strategy use, knowledge building, lack of regulation, engagement high-level question asking, and engagement low-level question asking scales were .89, .90, .85, .90, and .85, respectively (Shell et al., 2005; Shell & Husman, 2008; Shell & Soh, 2013).

Grades. Only students who consented to the use of their grades in the study were included in the dataset. The principle investigators retrieved those students' grades at the end of the semester by accessing University records. Because class sections differed, grades were transformed to standardized z-scores to facilitate analysis in SEM (see below for explanation of the analysis).

Analysis. Structural Equation Modeling was used to test the model illustrated in Figure 1. This analytic tool was chosen because the goal was to test linkages and potential mediating relationships among the included variables. These analyses were designed to model complex dependencies and the relationship among variables while minimizing error.

Follow-up analyses examined group differences in the SEM model between groups of female and male students. Follow-up tests also explored mean differences among male and female students on model variables.

Qualitative Phase

Participants & procedures. Phase two of this complimentary sequential mixed - methods study included conducting interviews with successful female students studying

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computer science and computer engineering (Creswell, 2013). As explained above, 'successful' is defined as obtaining a grade C or better in the course. This methodology was chosen due to the limited knowledge we have about successful women in computer science and computer engineering and because the low number of female students in the quantitative phase of this study precluded use of inferential statistics. The qualitative data complemented the quantitative findings by providing more explanatory information than the quantitative phase provided alone. This mixing of data led to a more comprehensive exploration of the research questions (Creswell, 2010; Creswell & Plano Clark, 2011).

Six one-on-one interviews with female students who were in good academic standing in the program (grade C or above in academic courses) were conducted over the phone using the recording service freeconferencecall.com (2001-2016, version W). Because we were unable to identify the racial diversity of participants during phase one of this study, I made an effort to recruit diverse participants for the qualitative phase of this study. I used several avenues to recruit students. I contacted the women's organization in the department of computer science, the multicultural student affairs office on campus, the university counseling center, and I collaborated with each computer science faculty member that taught undergraduate courses. I also contacted the Residence Hall Director who manages the residence hall where student's double majoring in computer science and business live. Each of these offices, organizations and faculty members were contacted because they potentially have contact with female computer science students and could refer them to my study.

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Interview data was audio recorded for further data analysis and transcription. I made handwritten notes during each interview – these notes added additional information to refer to during data analysis. Following Creswell's protocol for qualitative data analysis (2010), I first read the transcription and made additional notes regarding the data's content. Then, I categorized responses in an effort to identify key emergent themes. Next, I placed the interview data in a thematic design that provided a rich, detailed description of the characteristics of successful female students in STEM education courses (Creswell, 1998; Creswell & Plano Clark, 2011). Finally, I attempted to triangulate the data and analyze it to identify areas that the qualitative and quantitative data converged and/or contrasted with each other (Creswell, 2013). Triangulation culminated in a synthesis of the data.

Interview protocol. The interview protocol was created using other studies that investigated women students studying computing or engineering programs (e.g., Wilson, 2002; Cook & Córdova, 2007; Myers & Pavel, 2011). Each question was created based on hypotheses and findings from those studies. Students received an informed consent form asking for their permission to participate in an audio recorded interview and to inform them of their rights, the risks, and the benefits. After granting permission to participate, students were asked question's in eight categories:

1. The first category included general feedback questions. Students were asked about their general experiences in the course.

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2. Students were asked about the goals they set for their classes. For example, I asked students to describe the goals they set and how those goals changed over the semester.
3. Students were asked about their self-regulation habits. For example, students were asked how often they studied and the type of study methods they used.
4. Students were asked about their coping behaviors such as how they managed obstacles and stress, and how they handled failures.
5. Students were asked about the support systems they relied on for success in the course, including moral support, academic support and emotional support. Participants were asked to explain how they gained access to these support systems. They were also asked about the level of interaction/support received from classmates, faculty and university staff.
6. Students were queried about their prior experiences in science, technology, engineering or mathematics courses. Specifically, what courses have they taken previously, how they feel that experience impacted their performance in their courses, what courses students wish they had taken prior to enrollment and in what ways would they change their prior experience to be better prepared for the courses.
7. Students were asked to explain their career aspirations.
8. Students were given the opportunity to share anything else they deemed important about their experiences in an effort to assist other female students in experiencing similar success.

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Accuracy. Each transcript was sent to the interviewee for review of its accuracy and for inclusion/addition of any additional information that was not conveyed during the interview. After each transcript was approved by the interviewee, data analysis was conducted.

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Chapter 4

Results

Quantitative Phase

Structural Equation Modeling (SEM) was utilized to test a theoretically derived model of goal orientation, strategic self-regulation and course grades. SEM was ideal because of its ability to test multiple structural relationships. Mplus version 7.11 was used to perform the tests. Data were drawn from a multi-year dataset collected in a suite of Introductory Computer Science courses funded by multiple grants from the National Science Foundation (grant nos. DUE-1431874 & DUE-1122956).

There were 1,410 participants that identified themselves as majoring in a STEM area. Only students who completed the post-test and gave permission to access their grades were included in the study. In addition, there were 206 cases excluded from the study due to dropping out of the study prior to completing any of the measures, therefore analysis was run using 1204 participants. These excluded students indicated their gender, major and year in school but did not complete any of the measures (goal orientation & SRL).

The attrition rate of the larger NSF studies was approximately 30-40%. This attrition was largely due to the rigor of the courses and students' decision to discontinue the course if they performed poorly. Other students opted to discontinue the study but may have remained in the class. Chi square comparison tests were run on the 206 students that were excluded from the dataset for comparison to the 1204 cases that remained in the data set. There were no differences by gender between the two groups (χ^2

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(1) = 2.082, p =0.149). However, in terms of year in college, seniors were more likely to discontinue the study than the other grade levels (χ^2 (4) = 14.749, p=.005). Descriptive statistics are below in Table 1 and the χ^2 analysis data can be reviewed in Table 2 and Table 3, respectively.

Table 1

Descriptive Statistics

			Year in School					
			Freshmen	Sophomore	Junior	Senior	Other	Total
Gender	Male	Count	420	287	163	88	59	1017
		Expected Count	421.5	283.8	155.4	91.2	65.0	1017.0
	Female	Count	79	49	21	20	18	187
		Expected Count	77.5	52.2	28.6	16.8	12.0	187.0
Total		Count	499	336	184	108	77	1204
		Expected Count	499.0	336.0	184.0	108.0	77.0	1204.0

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	1017	84.5	84.5	84.5
	Female	187	15.5	15.5	100.0
	Total	1204	100.0	100.0	

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Table 2

Comparison of Excluded Versus Included Cases - Gender

			Out of Sample		
			No	Yes	Total
Gender	Male	Count	1017	182	1199
		Expected Count	123.8	175.2	1199.0
	Female	Count	187	24	211
		Expected Count	180.2	30.8	211.0
Total		Count	1204	206	1410
		Expected Count	1204.0	206.0	1410.0

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.082[a]	1	.149		
Continuity Correction[b]	1.788	1	.181		
Likelihood Ratio	2.202	1	.138		
Fisher's Exact Test				.169	.088
Linear-by-Linear Association	2.081	1	.149		
N of Valid Cases	1410				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 30.83.
b. Computed only for a 2x2 table

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Table 3

Comparison of Excluded Versus Included Cases – Year in School

			Out of Sample		
			No	Yes	Total
Year	Freshman	Count	499	85	584
		Expected Count	498.7	85.3	584.0
	Sophomore	Count	336	48	384
		Expected Count	327.9	56.1	384.0
	Junior	Count	184	22	206
		Expected Count	175.9	30.1	206.0
	Senior	Count	108	34	142
		Expected Count	121.3	20.7	142.0
	Other	Count	77	17	94
		Expected Count	80.3	13.7	94.0
Total		Count	1204	206	1410
		Expected Count	1204.0	206.0	1410.0

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14.749[a]	4	.005
Likelihood Ratio	13.648	4	.009
Linear-by-Linear Association	2.993	1	.084
N of Valid Cases	1410		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 13.73.

Analyses occurred in 4 stages. First, syntax was entered into Mplus and fit indices were accessed. The model fit indices indicated a good fit of the model to the data, X^2 = (40) = 63.538, p = 0.010, CFI = 0.983, SRMR = 0.032, RMSEA = 0.031 (CI: 0.015, 0.045). Next, each of the model relationships were reviewed, illustrated in Figure 2. The

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bootstrapping technique was used to test the indirect effects (research question 3) because it is a more powerful technique that impacts Type I errors and increases power. Also, the bootstrapping technique provides a nonparametric approach to statistical inference when distributional assumptions may not be met (MacKinnon, Lockwood, Hoffman, West, and Sheets, 2002). Significance using this technique requires assessing confidence intervals (Fritz & MacKinnon, 2007; MacKinnon et al., 2002).

Lastly, follow-up (post hoc) analyses were conducted to examine the relationship among the variables for female students and whether or not successful female students

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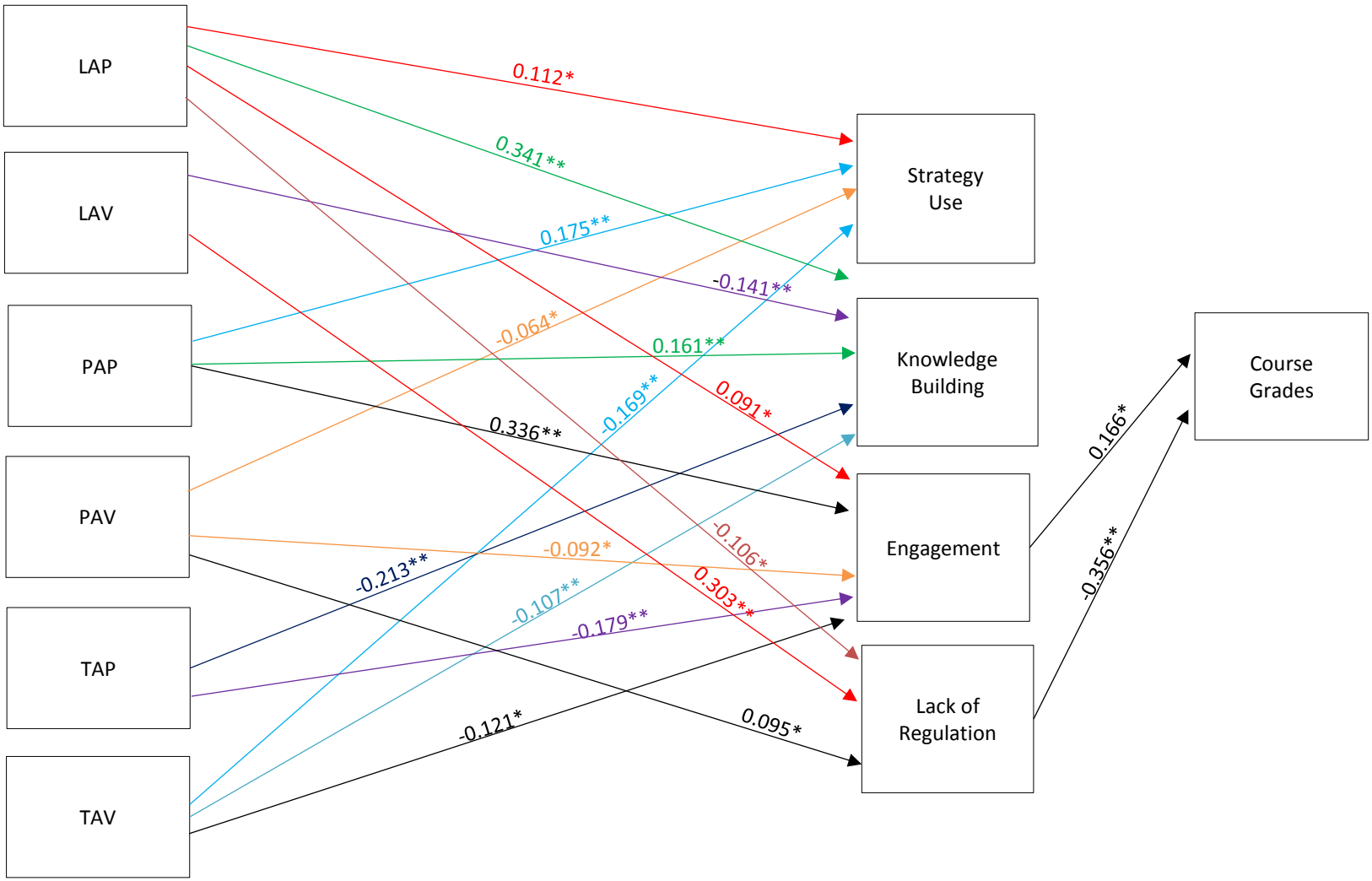

Model Fit Indices: X^2 **= (40) = 63.538,** p **= 0.010, CFI = 0.983, SRMR = 0.032, RMSEA = 0.031 (CI: 0.015, 0.045).**

Figure 2. Structural equation model of the relationship between Goal Orientation and Four Strategic Self-Regulated Learning (SRL) behaviors and SRL behaviors and course grades. LA=learning approach. LAV= Learning avoid. PA= Performance approach (normative). PAV= Performance-avoid. TA=Task approach. TAV= Task-avoid. * $p <$ .05, two tailed; ** $p <$ .01, two-tailed. Null pathways were omitted for clarity.

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Table 4

Means and Standard Deviations

	N	Minimum	Maximum	Mean	Std. Deviations
NGrade	1170	0.00	4.00	2.938	1.1840
GoPappsp	840	1.00	5.00	2.904	.9878
GoPavosp	840	1.00	5.00	2.819	1.1018
GoLappsp	840	1.00	5.00	3.935	.8622
GoLavosp	840	1.00	5.00	2.687	1.1375
GoTappsp	840	1.00	5.00	4.321	.7976
GoTavosp	840	1.00	5.00	2.631	1.0355
SPSelfRs	847	1.00	5.00	3.277	.8235
SPKnowBs	847	1.00	5.00	3.110	.8481
SPLackRS	847	1.00	5.00	2.833	.9414
SPQA	847	1.00	5.00	2.799	.9307
Valid N (listwise)	807				

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displayed higher levels of goal orientations and self-regulatory behavior patterns, as compared to groups of males. When assessing mean differences, Wald's Test of Significance was used.

Research question 1. What was the relationship between students' goal orientation and strategic self-regulated learning behaviors?

Learning approach (β = 0.112, p = < 0.01), performance approach (β = 0.175, p = < 0.01), performance avoidance (β = -0.064, p = < 0.05) and task avoidance (β = -0.169, p = < 0.01) goal orientations were each significant predictors of strategy use. Both performance avoidance and task avoidance negatively predicted strategy use while learning approach and performance approach goals positively predicted strategy use. Learning approach (β = 0.341, p = < 0.01), learning avoidance (β = -0.141, p = < 0.01), performance approach (β = 0.161, p = < 0.01), task approach (β = -0.213, p = < 0.01), and task avoidance (β = -0.107, p = < 0.01) were each significant predictors of knowledge building. Learning avoidance, task approach, and task avoidance each negatively predicted knowledge building while learning approach and performance approach were each positive predictors of knowledge building. Learning approach (β = -0.106, p = < 0.05), learning avoidance (β = 0.303, p = < 0.01), and performance avoidance (β = 0.095, p = < 0.05) were predictors of lack of regulation. Higher learning approach goals predicted less lack of regulation while learning avoidance and performance avoidance goals each positively predicted lack of regulation. Learning approach (β = 0.091, p = < 0.05), performance approach (β = 0.336, p = < 0.01), performance avoidance (β = -0.092, p = < 0.01), task approach (β = -0.179, p = < 0.01), and task avoidance (β = -0.121, p = <

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0.01) were each predictors of engagement. Performance avoidance, task approach, and task avoidance negatively predicted engagement while learning approach and performance approach each positively predicted engagement. The majority of these relationships were in the hypothesized direction and suggested that more adaptive goal orientations were associated with higher levels of adaptive self-regulated learning strategies/behaviors.

Two path estimates, however, contradicted the predictions within the conceptual model. The model did not suggest that task approach would negatively predict knowledge building or that task approach would negatively predict engagement and do not follow the direction of effect that the goal orientation and self-regulation literatures typically suggest (Schunk, & Zimmerman, 2012). See the Discussion section below for further interpretation of findings.

Research question 2. What was the relationship between strategic self-regulated learning behaviors and grades in the course?

Lack of regulation (β = -0.356, p = < 0.01) and engagement (β = 0.166, p = < 0.01) each predicted course grades. Lack of regulation negatively predicted course grades while engagement positively predicted course grades. As students reported higher levels of lack of regulation, course grades tended to be lower and students who reported being more engaged tended to also have higher grades. These relationships coincided with my hypothesis. However, knowledge building and strategy use did not predict course grades. This is somewhat surprising as higher levels of knowledge building is typically expected to predict good grades (students know more information presented on exams). In

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addition, students who employ adaptable strategies would be expected to also perform well academically because these strategies should allow them to retain more information and perform better when completing classroom assessments such as exams.

Research question 3. Was the relationship between goal orientation and grades indirectly effected by self-regulation behaviors?

Learning avoidance had a significant negative indirect effect on course grades through lack of regulation (β = - 0.108, 95% CI [- 0.149, -0.070], indicating that greater learning avoidance predicted greater lack of regulation and, in turn, lower grades. Learning approach had a significant positive indirect effect on course grades through lack of regulation (β = 0.038, 95% CI [0.006, 0.072]). Learning approach was associated with better regulation (i.e., lower lack of regulation) and higher grades. Performance approach had a significant positive indirect effect on course grades through engagement (β = 0.056, 95% CI [0.011, 0.102]), indicating greater performance approach goals predicted greater engagement, and in turn predicted higher grades. Performance avoidance had a significant negative indirect effect on course grades through lack of regulation (β = -0.034, 95% CI [-0.066, -0.006]) and engagement (β = -0.015, 95% CI [-0.036, -0.001]) indicating that greater performance avoidance goals predicted both less self-regulation (i.e., more lack of regulation) and less engagement, which each in turn predicted lower grades. Task avoidance had a significant negative indirect effect on course grades through engagement (β = -0.020, 95% CI [-0.043, -0.003]), indicating that greater task avoidance predicted lower engagement, and in turn predicted lower grades. Task approach, contrary to the hypothesized direct of effect, had a significant negative indirect

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effect on course grades through engagement (β = -0.030, 95% CI [-0.062, -0.005]), indicating that more task approach goals predicted lower levels of engagement and in turn predicted lower grades.

Most indirect effects estimates were consistent with my hypothesis and the literature and were consistent with the contention that adaptive goals were positively related to grades (e.g., Schunk, & Zimmerman, 2012). Conceptual models suggest that students with more adaptive goals (e.g. performance approach) tend to regulate their learning more effectively and were likely to be more engaged. Maladaptive goals tended to result in less adaptive study/learning behaviors, and predicted lower grades. Students who reported higher levels of learning avoidance goals, in particular, also tended to employ lower levels of self-regulation (i.e. more lack of regulation) and receive lower grades. Performance avoidance goals were related to higher levels of lack of regulation and lower levels of engagement and those behaviors were linked to lower grades. Students who reported higher levels of task avoidance goals, specifically, also tended to report lower levels of engagement that were, in turn, linked to lower grades. Students who set performance approach goals, in contrast, showed higher levels of engagement and engagement was linked to higher grades.

Contrary to my hypotheses, setting task approach goals predicted lower grades through engagement indicating that students who set task approach goals tended to be less engaged and in turn, received lower grades. This was not the expected outcome because task approach goals are those goals, for example, that students set to complete class assignments, exams or other tasks important for the course. Therefore, I expected

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this behavior to be linked to positive academic performance in the course. Possible interpretations of this counterintuitive effect are discussed below.

Post Hoc Tests. Are there differences in the model, factor loadings or means across gender groups?

A Wald Test of mean differences revealed that males and females significantly differed on performance avoidance (2.517, df = 1, p = < 0.01; 2.987, df = 1, p = < 0.01, respectively) and knowledge building (3.594, df = 1, p = < 0.01; 3.136, df = 1, p = < 0.01, respectively). Males reported engaging in more knowledge building than females while females reported setting performance avoidance goals more than males. There were no other significant differences in the factor loadings or model between males and females.

Qualitative Phase

Research question 4 (Qualitative). What were the positive, adaptive strategy use and goal setting characteristics of female students who successfully complete the STEM education course?

During the qualitative phase, I implemented a five-part process of data analysis (Ryan & Bernard, 2003). First, I conducted six audio-recorded interviews with five undergraduate students and one graduate student. I took handwritten notes regarding any interesting comments, emotion or emphasis that I could detect from voice inflection or metaphor use, etc. Table 3 lists the students (using pseudonyms), their grade level and academic major.

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Table 5 *Qualitative Phase Participants*

Name	Grade Level	Major	Interesting Note
Natalia	Graduate Student	Computer Science	
Robin	Senior	Management & Computer Science Major	2 Sibling and 1 Cousin in CS or CE program; Took JAVA senior year of high school
Patma	Sophomore	Management & Computer Science Major	Dad is a computer scientist
Cassy	Junior	Computer Engineering	Dad is a chemical engineer
Lauren	Senior	Computer Engineering	Took engineering class senior year of high school
Sarah	Senior	Computer Science & Math	

Second, I transcribed each interview using voice transcription software Dragon Naturally Speaking (version 13.0, 2015) by listening to the recording and repeating it aloud. This allowed the software to capture and type it automatically. I also utilized transcription software Express Scribe (NCH Software, 2015) which allowed me to slow the recording down for easier transcription and use keyboard keys to pause, rewind, fast forward and other commands instead of the computers mouse. Third, I read each document and corrected grammar and punctuation and filled in sentences using the handwritten notes, which provided context that may have been missing in everyday speech. Listing, re-listening, writing and reading the transcript was the initial phase of data analysis and provided a familiarity with each interview. During this process, common characteristics began to emerge (Creswell, 2013; Creswell & Plano-Clark, 2010; Ryan & Bernard, 2003).

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Fourth, I sent each transcript to the respective interviewee and instructed them to check for accuracy and to add any additional comments that needed to be included. Fifth, I began analyzing the transcripts. This process included uploading each document to qualitative data analysis software program MAXQDA (Version 12, 2015) and reading each transcript line-by-line individually and labeling interesting comments. These initial labels mostly revealed broad a priori themes that grew out of the interview question categories such as Goal Setting, Gender and Prior Stem Experience (see Appendix D for interview protocol). Next, I reviewed which words, behaviors, or qualities were mentioned most across all transcripts, which led to reorganizing the labels to group common ideas and creating new themes that represented the data more holistically and according to importance. Importance was determined by reviewing how often the theme was assigned and by considering the research question, "what are the positive, adaptive strategy use and goal setting characteristics of successful female students?" (See Appendix E for relative counts for each theme.) Comments that answered this research question were deemed appropriate for inclusion in the thematic categories. There were no highly mentioned ideas that did not answer this question. Finally, I assigned each of the six interviewees a pseudonym to protect their individual identity in this research report.

Four overarching themes and several subthemes emerged. The thematic characteristics of successful female students in undergraduate computer science courses were labeled: (a) the gender effect, (b) lack of computer science & computer engineering experience, (c) problem solvers, and (d) key influencers. Figure 3 illustrates these themes. The Gender Effect has one subcategory; Feeling Intimidated. Lack of Computer

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Science and Computer Engineering Experience has one subcategory; Transferable Skills. Problem Solvers has two subcategories; Collaboration and Study Behaviors. Key Influencers has five subcategories; The Village, Interest, Environments, Supportive Faculty and Career Connections. The Village has three subcategories; Parents, Siblings and Peers/Classmates. Supportive Teachers and Faculty has one subcategory; Teaching Styles. Career Connections has two subcategories; Performance Goals and Learning Goals. Each theme and subtheme, illustrated in Figure 3, are explained in the following section.

The gender effect. The successful female students studying computer science that participated in this research gave several examples of how gender impacted them in workplace, the classroom, and general educational environment. Lauren commented that, "Most professors know my name and it is a good feeling to know you are seen." She also lamented that this can be a negative thing too because professors are aware of when you skip class. Sarah stated that she felt a bit of special treatment at the beginning of the program because the professors really encouraged her. This 'special treatment' seems to be a result of faculty understanding the importance of having females in STEM fields and the potential negative impact of having so few females enrolled. Sarah asserted, "I could tell they wanted me to stay in the program. Also, I'm constantly getting social invitations from the department such as an ice cream social where I can meet women in computer

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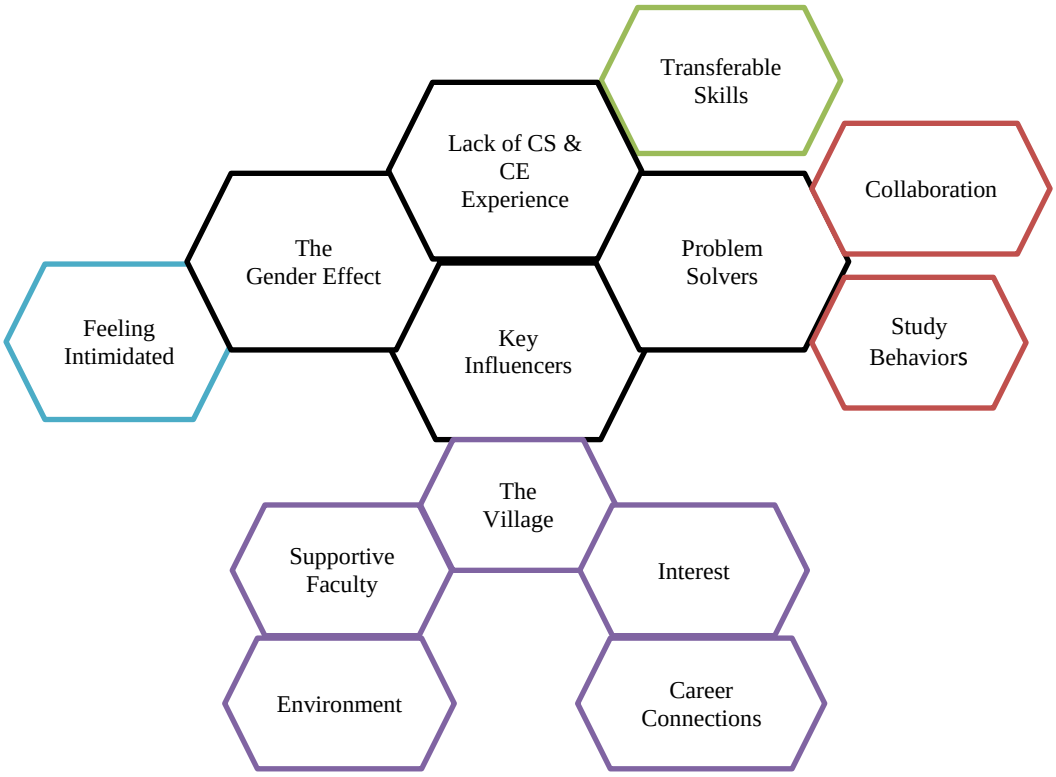

Figure 3. Pictorial illustration of qualitative themes and subthemes. Qualitative Themes: 1) The Gender Effect with subtheme Feeling Intimidated. 2) Lack of CS Experience with subtheme Transferable skills. 3) Problem Solvers with subthemes Collaboration and Study Behaviors. 4) Key Influencers with subthemes The Village, Interest, Career Connections, Supportive Faculty, and Environment.

science or other STEM fields." Natalia, on the other hand, spoke about the positive experience at her campus workplace. She said, "At my department the technology person for the whole department of 16 members is a woman and she does everything single-handedly. I work for her which makes me really proud." Conversely, Natalia stated that previously she had more negative experiences in the work environment. She explained, "As a recent graduate, I was in a few situations and I can't say for sure it was based on

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my gender. Most of the time the real work was done by my mentor and they wanted me to just document what he had done." As a result, Natalia was determined to get as much hands-on experience as possible because she was not entirely confident she could do the work.

There were many other comments associated with the small amount of females in the department and regarding the reality that there are not many females in the field more broadly. Students were unaware of what to expect upon entering the program. For example, Natalia explained, "I was the only female in one course apart from the teaching assistant. I was so surprised. I think it would be more comfortable if there were more females around because I don't think computer science is just a man's world." Soon students realize that there will not be many female classmates going forward and as Robin explained, there is a point where "you have to get used to the fact that everyone else in your class is probably going to be a guy. There's going to be one or two other girls in your class, maximum."

The data also revealed psychological implications such as self-esteem and confidence. Cassy said, "It's a little nerve-racking to be one of the few females in class because I feel like I have to have a higher standard of work which means working harder. I think having more females in the STEM fields will make being a female computer scientist more normalized." By this she meant that more females in the program could potentially normalize the fact that females can do computer science work well. Cassy attributes this feeling to "a lot of subtle cues from peers that make me feel like I have to prove myself a little bit more." There are several people that I know well that I feel like

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consider women lesser able at computer science in particular. Robin stated that being the only female meant "representing my entire gender. At least that's how it feels." She warned that, "As females in the field, people in general have a subconscious bias that we're not as competent as males. And if we're not careful, we'll start believing that about ourselves." Cassy supported this claim. She explained,

> Another thing about the computer science major is this imposter syndrome. It is the feeling that I don't belong here. A friend of mine who is a female computer science major got an internship at a company and was talking to one of her male friends about it. He responded by saying, "Oh, I didn't get that internship. You probably just got it because you are a girl."

Patma also expressed being frustrated that "guys sometimes try to get more guys to join their group project team." Also, she described, "While getting feedback on a previous assignment the TA [teaching assistant] was surprised I actually did well on it. Which means that they assumed I wouldn't." These comments from a male peer and the TA are two examples of how female students might develop insecurities about competence and question if they fit in or not.

The data also revealed some inherent differences that the participants felt existed between males and females. Sarah observed,

> Male students seem to have laser focus on a job. The guys are definitely surprised when they know that I do well in my classes and they tell me I can be this super awesome person that makes so much money. They don't quite understand why I'm not that focused on the job aspect of it instead of being focused on starting a family and building my career around that.

Robin also mentioned the cultural differences between males and females. She said,

> A lot of girls like to talk about going shopping, what they're wearing, and how they do their hair. Guys like to talk about sports. At my internship last summer, you could not have a conversation that didn't go to cars and sports.

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Lauren opined, “Girls like to talk a lot, we like to communicate so males and females will need different types of support.” Patma resolved that the gender issue meant that “you don't have the opportunity to take classes with more people who know what you're going through on a personal level.” This includes the feelings of exclusion, threats to confidence or concerns about career choices. These issues impacted classroom behavior and led to feeling intimidated.

Feeling intimidated. Several students provided examples of circumstances that make them feel intimidated. Robin confessed, “I believe I was the least knowledgeable person in class and because I was the only girl I would never ask questions in class.” Patma suggested that more females in the program would mean more diversity of opinions in class in terms of what course material needs to be clarified. She felt this might improve the way professors teach the material. Lauren noticed that female students are more willing to ask questions in class than male students but most of the time questions are not asked until after class. Cassy admitted, “I don’t want to ask questions in the class nearly as often because I don’t want to reflect on my gender.” But that “if more girls were in the class, more and different questions would be asked because most of the time guys don’t ask questions.” The low number of female students and the culture of knowing-it-all led students to behave in certain ways, such as not asking questions so no one will question their competence. However, that there are still other ways that students display being intimated about their level of competence relative to others. Patma described her experience with seeking out homework help. She stated,

> I was actually talking to my roommate yesterday about some implicit bias with going to our friends who are males for help when we have computer trouble as

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> opposed to our female friend's right down the hall who could equally help with solving a particular problem. I think there is an overarching feeling that one group was not doing very well compared to the other group. And that's a shame because beyond the introductory courses, we know we have the general coding and analytical skills in place because we've learned them.

There is also an assumption that other people are indeed working harder. Lauren said, "My classmates definitely know more and go the extra mile. So sometimes it's intimidating and there have been moments when I didn't think this was the career for me." Cassy felt similar as she commented that being judged by peers or judging yourself negatively "can really instill that sense that I haven't actually earned this; they are just giving it to me because I'm a girl. I don't actually belong here." These feelings of being intimidated seem connected to prior experience in computer science. Robin stated that because she decided to study computer science her senior year of high school, she sometimes feels intimidated because of her lower skill and knowledge level. In fact, lack of prior STEM experience, particularly computer science (CS) experience, emerged as a thematic characteristic of the study findings.

Lack of CS & CE experience. There was one commonality among each student in the study: they each completed high-level mathematics, at least Calculus I. Additionally, most of the participants reported completing high level sciences such as advanced placement physics and advanced placement chemistry. However, only one student took a true programming class offered by her high school. Robin explained how she gained access to the course. She asserted, "It was basically just our math professor who knew how to use JAVA and was willing to teach it. I took that class, loved it and went into computer science." However, this was her first exposure to the field and it was

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during her senior year. Most interviewees lamented that they wished they had taken more computer programming courses or anything STEM related. For example, Natalia stated, "I wish I would've gotten some training in programming languages. At least the basic ones like C++. I wish I had taken more coding courses, more technology courses." Robin also stated that participating in a coding course would have been beneficial. This lack of programming experience was especially salient for Patma because she "had a guest professor who was incredibly difficult especially coming in with zero coding experience." Cassy echoed this. She stated, "I was dealing with a lot of technologies when I came into CS that I didn't already know about. They weren't really teaching them in class either. So I was doing a lot of figuring things out on my own which was very difficult and frustrating." This lack of computing experience is not for lack of trying. Patma actually signed up for a coding class in high school but there were only three people interested therefore the class was cancelled.

There were other experiences that students wished they had. For example, Patma stated, "our school did have a robotics team but I never really found any interest in it. I should've done more on the programming uses of robotics to start learning more about software." Cassy explained, "In terms of computers, I only took basic computer courses where you learned about Microsoft Excel and Microsoft Word. I wish I had learned more about creating software programs instead of just using them." This lack of experience can lead to "being overwhelmed by what everyone else knew and trying to play catch-up," according to Lauren. Though the majority of interviewees had no programming experience they attested to other experiences that aided them in the CS program.

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Transferable skills. In a new academic environment that requires students to adapt quickly, prior experience is important. Sarah, for example, participated in weekly math competitions "where you'd be given really hard math problems and five minutes to try and solve them." Robin explained that her high school math teacher taught like a college professor and that prepared her for the CS program because she somewhat knew what to expect. In her opinion, teaching like a college professor meant covering a set of material on Monday and on Tuesday reviewing Monday's material briefly before diving right into new material. She also credits AP physics with preparing her for the CS program "because it was one of the most conceptually difficult classes I had in high school. So I gained experience working through concepts that I had not been exposed to before and how to study for AP tests. AP tests are like college finals." Though these classes were not computer science classes, participants reported that the rigor was useful. As Cassy stated, "by taking the hardest classes in high school, I think I prepared myself for college." Although these types of skills are transferable, most students admitted that they did not take the place of actual programming or CS courses. This lack of experience seems to be an initial obstacle but this cohort of successful female students met the challenge by running toward any problem they were presented with.

Problem solvers. An important deciding factor for ultimate success in the program is how the interviewees handled challenges. Each participant, to some degree, described a relentless desire to overcome obstacles by fiercely tackling anything that posed a threat to both mastering the material and obtaining high grades. This behavior appeared to be a response to having no experience in computer science or computer

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engineering, feeling intimidated by how much they perceived others students knew, the concern about being considered less knowledgeable or skilled and the belief that their gender was a crucial factor in determining their place in the program. These strategies were a combination of study behaviors and collaboration with other people. Generally, the participants had a "get – ahead" attitude. Patma said, "the big thing was to make sure I kept on learning and that I kept ahead." Lauren had a similar strategy. She said, "I try, depending on how the week before went, to get ahead. If it's a busy week I simply try to get everything done. But if I have an easier week, I try to get ahead or try to figure out what I can do earlier." Whenever faced with failure such as doing poorly on a test or homework assignment, most of the students responded by working harder. Cassy explained what happened after failing a test:

> During freshman year, I did very poorly on a test. It was my first computer science test. But after that failure, I reacted by working a lot harder. I went in to talk to the teacher a lot more to go over the various concepts we covered in class. And from that failed test, I got the highest score in the class on the second exam.

Failure was not uncommon among the interviewees. Natalia further explained,

> I did poorly on the second test and I decided to put it behind me. It's okay to fail because we all go through that. I decided to concentrate on the third and the fourth test and not worry about something that I can't control.

Additionally, depending on what the assignment load from other classes were, students described adjusting the priority level of different assignments and utilizing flexibility to stay on track. Students regularly monitored progress and treated completed goals as motivators.

Study behaviors. Students tended to work with several different types of course material, such as reading the textbook, reviewing notes, and solving homework problems,

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several times. Robin explained, “I work on class assignments, look over my notes, look at extra resource documents professors might put online, read the textbooks and take notes on the textbook too. She also rearranges information after further processing.” She explained, “I try to rewrite my notes to make them more similar and try to reorganize the concepts into similar groups.” All of the participants reported studying daily. For example, Patma said, “I'm always working on at least two classes a day doing either homework or studying for an exam.” She had the longest study day among the group, spending up to eight hours on weekends and until 1:30 am on weekdays. Along with reading texts, reading, writing and reorganizing notes, students spent time practicing problems. Cassy deliberately did a lot of problems manually. This way, she explained, she can avoid using the tools that a lot of programmers rely on. Although students used multiple strategies, it was difficult for students to explain where they acquired these study skills. Most attributed this learning to family, a teacher prior to college or trying different things over time. For example, Lauren remembered, “our high school had a very big focus on introducing new study methods. They showed me a variety and I picked which ones worked best for me.”

Several of the participants utilized a to-do list. Natalia provided details. She explained, “if I get really stressed, I consider leaving some things off of my list. I don’t think about them again until I finish one or two other things. Then I keep knocking things off my list.” Sarah, on the other hand stated, “I’ll go through all of the lecture notes multiple times and cram as much information as I can onto a reference sheet [that the professor allows me to bring in class].” She studies the information so intensely that she

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no longer really needs the reference sheet once exam day arrives. When faced with failures, most students reacted by studying sooner, spending more hours studying or trying different strategies. In fact, the study repertoire used by each student was mostly the result of a refinement process as Lauren alluded too; trying different things until the desired result was achieved. In addition, all students mentioned the value of studying with other people.

Collaboration. Studying with other people was important to several participants for a number of reasons. For example, Sarah explained, "it really helps because a lot of times the students that I pair up with aren't doing that well in the class and I have to understand it well enough to be able to teach it." Teaching the material to others was also mentioned by Robin. She said, "it helps to work with other people because you can bounce your ideas off of them and explain to them how you understand it." Lauren stated, "having classmates in the same classes that you can bounce ideas off of if you are stuck" is an important way to excel in the course. Cassy agreed that working with other people "helps because explaining the process to another person actually helps me understand it better." Working with other people is so important to Cassy that she takes steps to be in class with people that she works well with. Both Lauren and Cassy asserted, "I do my best to take classes with people I already know and with my friends because that makes it a lot easier when doing homework or studying that I have someone to bounce ideas off of and study with." She also cautioned that there are two types of collaborators. Cassy warned, "there's those collaborators who are supportively competitive versus those that are selfishly competitive. I had to find people to work with who were supportive." Patma,

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however, explained that due to an apparent instance of student cheating, one of her professors is limiting collaboration among students. She explained, "If you get any help from the textbook, a TA, or any other person, you have to cite that in your homework as a source. Is has gone to a ridiculous process of self- learning and has been detrimental to learning." This students' reaction to the prohibition of working with other people illustrates how important collaboration is to these students who are studying computer science.

Key influencers. While students seem self-motivated and determined to be successful in the CS program, as a group they frequently mentioned other people and things that influenced that success. These key influencers served as both catalysts and sustainment. The participants shared stories about how they relied on people to stay focused both in the short and long term. They also explained what they gained from these relationships. The findings revealed that these relationships positively influenced success and provided an emotional outlet for the participants.

The village. The first key influencers that I will discuss are referred to collectively as *the Village.* The Village consists of parents, siblings, and friends. It should come as no surprise that participants alluded to their parent's influence. Some of them learned by watching how their parents handled work while others received direct feedback and tutelage. For example, Patma explained, "My dad has a fantastic work ethic. I take that into account and I want to be that type of person. I continue to assume that I shouldn't be anything less than the highest I can be." Cassy had a similar experience at home. She shared,

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> My parents have always been very hard-working. My dad graduated high school and didn't go to college. He went straight to work as a truck driver. After 20 years, he's now manager of that company simply from working hard and learning as he went. So I learned the value of working hard very early.

Cassy and Lauren both explained how their parents pushed them and held them to a high standard. Lauren said, "My parents know what I'm capable of and they have always held me to that standard. They push me. When I feel like not trying anymore, they've always reminded me that it's all worth it in the end." Parents also rewarded hard work. Cassy explained, "My family always says how proud they are of me, that all this hard work it's going to be worth it." Similarly, Sarah said, "if I do really well on a test, I'll take a picture and send it to my mom. She will get really excited and it feels good to see her text message full of excitement." Sarah went on to say that while her dad was a perfectionist, "Mom helped me focus on long-term goals instead of nitpicking every little thing." Robin, on the other hand, revealed, "Sometimes I get really stressed out and I'll call my parents. They'll remind me to take a deep breath, prioritize, and make sure you get enough sleep." These examples illustrate the role of parents in the lives of these young ladies. Although two participant's parents had a computer science or engineering background, the others did not. This suggests that even though some parents are not knowledgeable about computing fields, they nonetheless provide support that makes an impact.

One of the participants has relatives who are studying computer science or computer engineering. These relatives served as ambassadors while in the program, recruiting them to major in CS or CE and also as role models. They provide homework help, explain what to expect in classes and are an overall guide in the program. This can

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be extremely helpful especially if you have had no exposure to CS or CE while in high school. Conversely, Sarah explained that her younger brother was a juvenile delinquent and he served as someone who motivated her to do better. For Sarah, he served as "an example of how you can crash and burn if you don't put in the effort, so you need to make sure you don't end up on the wrong path."

Peers and classmates also seemed to be influential for all of the participants. Natalia explained that she has friends that she depends on for emotional support and that helped her learn to study. Patma and Natalia both make certain that they take classes with friends so they can more easily form study groups. Cassy described finding a friend who became a study partner. She explained, "I was lucky enough to have an early-morning class with another student who ended up being my support system throughout various classes going forward." Similarly, Lauren explained how her friends are all good students so they do not interfere with her study schedule. Even though they are not in the CS program, she can count of them to study with her and not be distracting. The importance of peer groups seems to relate to the anxiety felt by students in terms of being the only female. As alluded to above, male students who want to partner with male students presents a challenge for female students to find students they can collaborate with. These students understand that challenge and respond by being persistent. They have found students who they interact well with regardless of gender and they frequently rely on their Village when they get discouraged. In short, the village consisted of students not in the program, parents and siblings or CS classmates they have built a relationship with. Finding classmates has not necessarily been an easy task. Lauren felt lucky to have found

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a collaborator and she concluded, "I might not have my best friend in class but I still can talk to them and go to them for homework help."

Interest. Several participants expressed that being interested in the coursework helped them stay motivated to contend with its rigor. Natalia asserted, "My interest has kept me in the program. This is what I like to do so I have never thought about leaving the program." Sarah similarly discussed her interest. She said, "the classes are keeping me interested. I can actually see myself using the material that they are teaching in industry once I have a career." Robin described her interest in computers as something mystifying. She explained, "it is this magic box that does whatever you want it to do when you click on things and I wanted to know how that actually worked. I found out that it's really cool." Patma described her interest in leadership and how it correlated with a CS career. She stated, "I want to be a leader. The CS program that is combined with the business school was incredibly interesting to me because I want to be involved in both a fast-paced business world and a technology environment." Lauren even described her interest being peaked in spite of her lack of CS experience. She said, "I'm really interested in how applications look visually. I am interested in what users like and dislike." Additionally, Lauren insisted that if someone had come to her high school and explained computer science, she would have become involved earlier. She certainly felt that was a missed opportunity.

Environments. Apart from the instances where males want other males to join their study groups, the interviewees had some positive feedback about the CS environment on campus. For example, Sarah explained, "going to programs [that the CS

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department sponsors] helps me stay on track and see other women who are successful in STEM. It makes me feel confident that I can be successful too." They also had advice about how to improve the environment for women students. Robin suggested that young students join a club in the CS department during freshman year. She explained that by doing this, female students have an excuse to ask stupid questions and that helps deal with feeling intimidated by what everyone knows. Cassy stressed that, "finding people who really help show you your purpose to help you realize your value is very important when you are in that kind of environment [that lacks many female's students]." Lauren suggested that merely "having freshman meet female computer engineers will create a support system. We must create environments where females know that there are other females with them and they're not alone." Cassy felt that it was important to find other females in STEM because "you will have people who will say that it's not a real problem and that can be very frustrating because some people just don't see the kind of things that you see." An example of a problem that everyone may not notice is workplace culture. Patma described the males at her internship at a large technology firm as "brogrammers." She said,

> In this type of culture, you have expectations but the guys want to look like they're laid back. I've heard it described as 'aggressively casual.' They're trying so hard to be cool that it's kind of overwhelming. You wonder, 'is that due?' Or, 'is that my responsibility?' You are confused about what's going on. You don't know exactly how you're being evaluated because you don't know what's expected. I routinely feel like I don't belong. I walk to work thinking, 'this is going to be an interesting day.'

The importance of the environment was not limited to college and the workplace. Several participants suggested that high schools and parents take steps to create an inclusive

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environment where girls feel capable and encouraged to do math and science. Sarah mentioned the impact of early CS exposure. She said, "early exposure is better versus in middle school when you are going through puberty and you're so worried about what everybody else thinks about you. You have to decide if you want to be nerdy, or if you want to be the cool kid." Introducing younger girls to math and science in elementary school can reduce the influence of peer pressure that some students feel in middle school.

Faculty. The interviewees reported that professors in the CS program have been extremely supportive. They offer their time to students to clarify any misunderstandings and also support them as females in the program. Sarah explained, "the professors keep good office hours and have an open door policy. As long as they're not busy you can go into their office at any time." Patma was also impressed with faculty. She said, "Professors are incredibly great at introducing me to new fields whether that's data mining, computer science in general or more of the analytical process behind things." Professors were also instrumental in helping students identify careers. Lauren lamented, "they always try to find you opportunities. They invite companies to campus, they teach you how to talk to the company's. They are always thinking about your long-term success." However, there was feedback that suggested faculty needed to reconsider their teaching style. Cassy complained that one of her professors "taught at too high of a level. It seems as though some teachers understand things at such a high level that they have a hard time breaking it down into the smaller, lower level concepts." However, she still had a positive experience with this professor. She explained, "But when you went to his office and talked through it with him he was able to see where you individually

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misunderstood it and he could break it down further for you." Lauren concluded, "Professors are all very willing to help if you come to them and asked them for help. They will definitely go outside their office hours to make sure that they find the time for you."

Career connections. Job prospects also served as a key influencer for students. Because technology is ever changing, as Natalia pointed out, students are concerned about where they will work, what type of job they can obtain, and what ongoing learning needs to take place. As a result, several students reported that they set specific learning goals (to review types of goals, see chapter 3). Cassy said, "I don't know what I want to do yet so I want to learn it all. And maybe that will help me figure out what I want to do." For Cassy, career prospects are directly related to setting learning goals. Lauren, on the other hand, was working in an internship which made it clear how to connect classroom learning to the workplace. This also motivated her to set learning goals so that she could apply more concepts at work. In fact, several students reported setting learning goals, regardless of the grade they receive, due to anticipated success in future careers. Sarah explained, "I set the goal of doing the best that I can even if that means that I'm going to end up with a B." Robin agreed. She said, "I set goals just to learn the material the best that I can. I want to do well on projects and homework because it's a good gage of how well you understand the material. My focus is more on learning and understanding the concepts than on the grades." Cassy made a sobering comment in her conclusion about the importance of learning the material. She said, "I really want to learn and understand

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the material because this is the field that I'm going into. If I can't figure this material out, then I don't belong in this field."

In addition to setting goals to learn the material (i.e., learn approach goals), students also set goals to perform well (i.e., performance goals). This too seemed connected to job prospects. Patma explained, "An ever present goal for me is to get an A; regardless. To me that's not a goal, it is a lifestyle." Sarah explained why so many students set performance goals. She said, "It is really competitive on the job market. For example, I know a lot of people will say that your GPA isn't that important. However, in computer science I've been told over and over that your GPA matters." Along with learning goals, Cassy also set performance goals. She said, "I very much push myself to be a high achiever. I always push myself to do the best in my courses especially computer science courses. I want to get an A." And she explained this desire to want to get a high grade was the result of feedback that she gets from companies. She said, "having a very high GPA is a nice eye catcher. It makes you stand out. I've had several companies comment on my high GPA." Though getting high grades was a common goal among the participants, Patma thought of one situation in which her learning goals might falter. She explained,

> I guess the learning would drop off if there were too many competing assignments. In that case, learning would be forced out. I'm still doing all the work assigned but learning beyond that would be neglected only if completely necessary.

Synthesis of Qualitative and Quantitative Data

The present study employed a complimentary mixed-method sequential methodology in which quantitative data was analyzed first and qualitative data was

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examined second. As a final step, these findings need to be integrated and synthesized. According to Johnson, Onwuegbuzie, and Turner (2007), this convergence of findings serves to enhance what we understand about a particular cohort or phenomenon. This research is a complimentary mixed-methods study, in that the second phase not only provides rich qualitative data that the quantitative phase cannot reveal but is also collected to help compliment the quantitative data and possibly explain the phase one findings that may not be immediately clear (Creswell & Plano Clark, 2010; Johnson et. al., 2007). In addition, the process of triangulation combines methods in the study addressing the same or similar research questions in an effort to diversify the methodological approach (Johnson et al., 2007). There are three possible outcomes of data triangulation. They are: convergence, inconsistency, and contradiction (Johnson et al., 2007). After analyzing both sets of data in this research, and stepping away from them to think about how they compare or contrast, I have concluded that the findings and data analyzed here converge more than they do not (Creswell, 2013). I provide several examples of convergence below.

The quantitative data revealed that learning approach goals predicted student's adaptive strategy use. The qualitative data supported a similar association. For example, Robin explained that her focus was on learning the concepts and understanding the material more than on grades. As result, Robin uses a reorganization study strategy. She explained, "If I find particular bullet points on my notes are similar, I try to rewrite them to make them more similar and reorganize the concepts into similar groups." This technique helps her both remember the material and apply it in real world settings. The

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SEM analyses also indicated that performance approach goals predicted greater strategy use. Patma explained, "I am very self-motivated. I want to show myself as the best I can be and to make sure that I perform at a high level." Therefore, she "spends eight hours each day studying for various classes and on weeknights I probably study until 1:30 AM." Similarly, the model results also showed that learning approach goals predicted higher levels of knowledge building. Cassy explained a similar link in her interview saying that, "I practice writing methods by hand so I make sure I know exactly how to do them without relying on tools a lot of programmers use. I do a lot of manual stuff." Performance approach goals were also linked to greater engagement in the quantitative phase and, perhaps most importantly linked to better grades. Similarly, many of the interview participants explained how their goals to learn and perform well resulted in engagement with classmates and professors. Robin elaborated on this by saying, "If I don't understand the concepts that might be on the exam, I will talk to my professor about it or I'll do a study group with friends and talk through the concepts." Examples included asking professors clarification questions or working with classmates in study groups.

The qualitative data may also help explain a surprising result from the quantitative phase: task approach goals negatively predicted engagement and also task approach goals had a negative indirect effect on grades. Task approach goals predicted lower engagement and in turn, predicted lower grades. Some of the qualitative participants perhaps indicated a possible explanation by describing the competitive nature of computer science. This may mean that focusing on doing well without also focusing on

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doing better than others (i.e., maintaining a strong, parallel competitive orientation) may be maladaptive in highly competitive settings. While the potential aspect of multiple goal orientations was not examined in analyses, Sarah's interview explained, "It is really competitive on the job market. If I want to work for Google or Microsoft, I need to put my best foot out there to make sure that I can stand above other applicants." Cassy suggested that "there was a significant number of students in the CS program that have the competitive attitude of having to be right." These two examples suggest that "doing well" *and* "doing better" might be particularly important for this group of interviewees because doing better than others and doing well are *both* necessary for securing employment.

Finally, the qualitative findings complimented the mean differences found among males and females in the quantitative phase. Females had a higher level of performance avoidance goals and males had a higher level of knowledge building. Patma admitted, "I should've scheduled more time for side projects in addition to doing computer science as an academic thing. I should have made more time in my personal life so that I learn more about it." Lauren made a similar comment. She said, "My male classmates definitely know more and go the extra mile. They do CS stuff in their free time and I prefer to do other things." In terms of performance avoidance goals, some students described how they attempted to avoid looking incompetent. Many of them reported that they avoid this by not asking questions in class. In fact, Cassy worried about making her entire gender group look bad. She said, "I don't want to ask questions in the class nearly as often because I don't want to reflect on my gender." Robin, on the other hand, had a remedy

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for this. She argued that students should "join an engineering or computer science club while you are a freshman in college so you have an excuse for asking stupid questions."

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Chapter 5

Discussion

This mixed-methods research study examined successful female students in computer science at a large Midwestern university. The first phase consisted of examining students' self-reported self-regulation and goal setting behaviors collected by administering electronic surveys. The second phase included conducting six in-depth interviews (a case study) with successful female students studying computer science or computer engineering, which complimented the quantitative data. This study aimed to address the gap in the literature regarding the patterns of motivation and self-regulation behaviors of successful female students in CS and CE as well as their qualitative characteristics (Cohoon, 2001; Harper, 2010). A goal of this project was also to describe how female students in this academic area have been able to be successful despite the challenges they face in pursuing and persisting in STEM fields, including computer science (Li et al., 2009; Marra et al., 2012). The following discussion includes three sections: (a) research questions, (b) conclusions and recommendations, and (c) limitations and future directions.

Research Questions

Research Question 1: Was there a relationship between students' goal orientations and strategic self-regulation? Learning approach and performance approach predicted greater knowledge building. This means that students who set goals to learn as much as they can and perform well also reported strategies designed to increase the amount of knowledge they acquired. Additionally, consistent with hypotheses,

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learning avoidance and task avoidance each negatively predicted knowledge building. As predicted, those who set avoidance goals tended to perform more poorly. Also, students who set learning and performance avoidance goals tended to report a lack of regulation while students who set learning approach goals tended to report lower levels of lack of regulation. When students set learning approach and performance approach goals, they reported higher levels of engagement in the course than students that reported setting higher levels of performance and task avoidance goals. Learning approach, performance approach, performance avoidance, and task avoidance goal orientations were each significant predictors of strategy use. Students who indicated that they set goals to learn the material and perform well also tended to report more adaptive study strategies such as note taking, practicing homework problems and reading textbook material. Both performance avoidance and task avoidance, in contrast, predicted less adaptive strategy use.

These findings are consistent with my hypothesis and the models and findings currently presented in the literature (Hazley, et al., 2014; Pintrich, 2004; Wolters et al., 1996). They also extend what we understand about the ways in which goals inspire self-regulated learning. While previous research found that students set adaptive goals at the start of the semester, they may change these goals to less adaptive goals (Hazley, et al., 2014). The findings here suggested that perhaps students may also set the type and frequency of study habits they employ based on the goals they are pursuing. These strategies could change along with goals.

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These findings supported our theoretical understanding of how goals impact behavior but they also provided new insights about goal setting and study behavior. This was important specifically in computer science and computer engineering because successful female students have rarely been a distinct focus of research (Nelson et al., 2015; Senko et al., 2011; Wolters et al., 1996; Zimmerman & Martinez-Pons, 1990).

In contrast to the support for my hypotheses above, however, task approach goals negatively predicted knowledge building and engagement. This result is clearly inconsistent with current models and empirical findings (Shell & Husman, 2008; Shell & Soh, 2013). Task approach goals are those goals that students set to do well on homework and other assignments without regard to other students' performance while performance approach goals are considered to be normative (desire to best peers). Previous research results suggested that normative goals could be maladaptive because they require demonstrating competence relative to other people (Senko et al., 2011). It is possible that the competitive nature of computer science, as suggested in the synthesis of phase 1 and phase 2 findings (see Chapter 4), could mean that students more often set performance goals. In addition, the importance of achieving a high GPA (because employers place value on it) could also lead to students' desire to have 'the highest' GPA among their peers. This both demonstrates competence and helps a student stand out among a field of job applicants. Although task approach goals and performance goals were correlated in this study ($r = .30$; $d = .09$), the effect size is considered small (Cohen, 1988). Nonetheless, we can argue that the competitiveness of the courses and of the students in

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this group of participants may mean that task goals (completing assignments well/getting good grades) without regard to how others are performing may be maladaptive.

Research question 2: What was the relationship between strategic self-regulated learning behaviors and grades in the course? Lack of regulation negatively predicted course grades while engagement positively predicted course grades. These findings are consistent with the literature (Hazley et al., 2014; Pintrich & De Groot, 1990; Shell & Husman, 2008; Shell & Soh, 2013) and extend it by investigating it in a female STEM context. Students who fail to regulate their learning are more likely to earn lower grades. The rigor of course work in computer science requires students to use a plethora of study strategies in order to keep up with the workload. Those students who do not have study skills are at risk of achieving lower grades. The qualitative data also support the idea that engagement predicts performance. Technology is a field that is ever changing and constantly refined so students will need to remain engaged with the courses and classmates and eventually with co-workers and supervisors in the workplace in order to stay abreast of computing techniques and theoretical approaches as they change. This academic program requires students to be aggressive, proactive and to recover from failure quickly.

Research Question 3: Was the relationship between goal orientation and grades indirectly effected by self-regulation behaviors? There were several goals that indirectly predicted grades through strategic self-regulation and engagement behaviors. Students who reported greater learning avoidance goals also showed higher levels of lack of regulation (i.e., lower regulation) and in turn, lower grades. Conversely, learning

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approach goals predicted lower levels of lack of regulation. Students who set task avoidance and surprisingly, task approach goals also showed lower levels of engagement and that behavior was linked to lower grades. Performance avoidance goals were related to lower levels of engagement and greater lack of regulation and each of those behaviors were related to lower grades. Students who set performance approach goals showed higher engagement and that behavior predicted to higher grades.

These findings, in general, add to the literature because the indirect relationships between goals and strategic self-regulation/engagement have been less thoroughly studied (Hazley et al., 2014; Shell & Husman, 2008; Wolters & Rosenthal, 2000). These findings suggest that goals can have an important indirect impact on grades by influencing more specific student behaviors (Elliot, 1999; Senko et al., 2011). For example, if students make a decision to perform well in class, that may propel them to be more engaged in the course by asking questions and forming study groups with peers. As prior findings suggest, these behaviors also tend to lead to higher grades in the course (Elliot, 1999; Senko et al., 2011). This is important because it clarifies more precise ways in which goals may drive behavior, including the type and possibly the frequency of adaptive behaviors. We know from previous research (i.e., Middleton & Midgley, 1997; Nicholls, 1984; Pintrich et al., 2000; Rawsthorne & Elliot, 1999) that adaptive goals typically lead to positive outcomes such as performance and persistence. This study elaborates on that contention by describing more specific behaviors that students likely engage in to reach their goals.

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An unexpected finding produced here, however, was that setting task approach goals was linked to lower levels of engagement and thus to lower grades. As discussed above, in the highly competitive environment of this program, higher levels of task approach alone may not be associated with greater engagement and higher grades. If task approach goals indicate a focus only on completing the course content and solving the problems without a focus on performing competitively, then those goals may lead to less engagement in the competitive aspect of this computer science/computer engineering program. Therefore, it may be adaptive, in this case, to be focused on both getting good grades (task goals) *and* on besting peers (performance goals). Being academically competitive is likely to be important to demonstrating your level of skill ability in computing fields and to engaging with peers when at least a portion of that social engagement may be frequently linked to a culture of competition. This is an important finding that seems to illustrate the consequences or uniqueness of a competitive academic environment.

Ad Hoc Follow Up Tests. Are there differences in the model, factor loadings or means by gender? The means for males and females significantly differed on performance avoidance and knowledge building. Males tended to report being engaged in greater knowledge building while females, on average, reported being engaged in more performance avoidance. In research conducted by D'Lima et al. (2014), the opposite finding emerged. D'Lima and colleagues did not, however, include students studying computer science or computer engineering. This finding extends the literature and perhaps sheds light on the challenges associated with being female in these types of

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competitive, male dominant environment. The synthesis of the quantitative and qualitative data in this research (see Chapter 4) may provide a partial explanation. Many of the interviewees reported a level of anxiety about male peers and professors viewing them as incompetent, especially because they had relatively little prior computer science experience. Some of them took steps to avoid being viewed as less knowledgeable such as asking fewer questions in front of the class and studying more. Likewise, the synthesis of the data may have helped explain why the mean for knowledge building among males was higher. Some of the interviewees admitted that male students spend more time working on computer science skills and concepts beyond regular coursework, more so than some female students. Perhaps males are accustomed to the competitive culture of computer science and computer engineering and understand that males are stereotypically considered highly competent in the field. This realization may lead males to study more. Campus and department culture can also influence students to behave in certain ways and if CSCE encourages males to know-it-all, then it follows that students will try to meet those expectations. Female students, on the other hand, who often (according to the qualitative data collected here) start the program less skilled and who have not been a part of the competitive computer science/engineering culture may engage in fewer knowledge building activities than males.

Research Question 4: What were the positive, adaptive strategy use and goal setting characteristics of female students who successfully complete the STEM education course? The students who participated in this portion of the research study here reported setting mostly learning and performance goals. They set learning goals

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because they desired to have a deep understanding of the material and enjoyed the content. To achieve learning goals, students created study schedules, collaborated with peers and sought clarification from professors when necessary. Learning goals were sometimes impacted by the desire to perform well, including instances when the workload required student to prioritize grades over learning additional concepts. Students set performance goals as a means to secure future employment, to remain motivated while faced with difficult classwork, and to prove they had learned the material.

The interviewees also engaged in several adaptive strategic-self-regulation behaviors. Some of these behaviors mentioned were reading the textbook and lecture notes multiple times, taking notes on the textbook or during class, adding to notes after learning or clarifying a previously introduced idea, reorganizing notes such that similar ideas are grouped and learned together and practicing skills such as binary searches, recursion and exploring different coding languages. They also prioritized assignments using to-do lists, monitored progress and revised priorities as necessary, and explained the material to other people to ensure an in-depth understanding.

These are all adaptive behaviors that these students reported as important to their success. As previous research findings have suggested, the prior achievement hypothesis, (i.e., that female students do not have adequate prior math and science skills to be successful in computer science or computer engineering) does not seem to hold in this research (Riegle-Crumb, King, Grodsky, and Muller, 2012). For example, five of six students in this study reported entering the computer science or computer engineering program with no prior experience in the field, yet a combination of goal setting, strategy

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use and finding a supportive group of people have resulted in a high level of success and positive academic performance. In addition, each student reported taking advanced math and science classes during high school – this also suggests that the prior achievement hypothesis may not explain the enrollment disparities between males and females (Ehrenberg, 2010; Holdren & Lander, 2012). It is reasonable to assume that female students may have the necessary underlying skillset, even though they less often have the same level of prior specific computing knowledge as many males, to be successful in the field.

One of the major barriers for women in computer science, as illustrated by the testimony of the women in this study, is that gender issues inherent to the computing industry and academic environment pose obstacles likely equal in magnitude to the academic rigor required for the coursework. Students consistently reported feeling excluded by male students (e.g., when working on group projects) and felt that their competence was questioned despite academic evidence of performance, and discomfort in male dominated spaces inhabited by "brogrammers" (Cheryan et al., 2009; Hernandez et al., 2013; Perez et al., 2014). Spaces that brogrammers occupy were described as "aggressively casual," where implicit rules were adhered to among the males in the group. These gender based social issues and gendered group norms seem to be pervasive and intrusive despite the level of skill, motivation and strategy use that each of the women interviewed here demonstrated (Varma, 2010).

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Conclusions & Recommendations

This research addressed the gap in the literature about the motivation and self-regulation behaviors of successful female students' studying in STEM fields. It is clear that female students who are successful appear more likely to take more aggressive steps to acquire the knowledge necessary to perform well and learn the material. They reported that this was accomplished by setting adaptive goals, incorporating study strategies and maintaining a diverse support group that included professors, classmates, friends and family members. Although it was common for the students in the qualitative portion of this study to report that they entered this academic area lacking relative computer science skills, they did show prior experience in other related areas, such as high-level math and science experiences. Through this experience they were able to rely on transferable skills that they likely learned while taking those difficult classes in high school (Ehrenberg, 2010; Holdren & Lander, 2012). Most students in the qualitative study also indicated that they had wished they had taken more programming classes and had taken the opportunity to learn one or two coding languages prior to college entrance (see Chapter 4). This prior knowledge could have helped to alleviate the pressure of "playing catch-up" while learning new concepts in a rigorous, fast paced academic environment. Based on these findings, I have compiled six recommendations intended to help other female students be successful in computer science.

Recommendation 1. K- 12 institutions should implement more comprehensive computer science and computer engineering programs beginning in elementary school and should make every effort to incorporate computing field content into the curriculum

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as stand-alone programs and courses. Students in this study explained that limited access to computing coursework and training during their K-12 education has had a negative impact on their academic success in college. For example, Natalia stated, "I wish I would've gotten some training in programming languages. At least the basic ones like C++. I wish I had taken more coding courses, more technology courses." This lack of programming experience was especially salient for Patma because she "had a guest professor who was incredibly difficult especially coming in with zero coding experience." Curriculum changes and hiring additional fulltime personnel can be expensive and time consuming, therefore one strategy may be for administrators to make computing programs accessible after regular class hours when students could participate in extended day programs or extracurricular clubs and later incorporate them into the regular curriculum. However, teachers should be intentional and aggressive in terms of helping students see the range of benefits that these extracurricular programs offer. For example, Patma stated, "our school did have a robotics team but I never really found any interest in it. I should've done more on the programming uses of robotics to start learning more about software." School districts should also consider hiring computing professionals to teach courses to mitigate the shortage of trained teachers with this skill set. Professionals can teach on a rotating basis and be trained to deliver appropriate classroom management to ensure success.

Recommendation 2. In terms of extracurricular activities that occur outside of the classroom, female students should be introduced to science and math concepts by expanding clubs, competitions and project-based programs early in their academic

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timelines. Schools should endeavor to implement and expand programs such as Girls Who Code, Black Girls Code or NCWIT Aspirations for Computing (see girlswhocode.com; www.blackgirlscode.com & https://www.aspirations.org/) to attract and train diverse female students. This is key, in part, because these opportunities offer important transferable skills to later coursework and the computing fields (Ehrenberg, 2010; Holdren & Lander, 2012). It is reasonable to assume that some K-12 schools simply cannot afford to implement formal or extracurricular CS/CE programs. Therefore, high-level math and science curriculum is minimally required for later success in CS/CE. Robin explained that she credited AP physics with preparing her for the CS program "because it was one of the most conceptually difficult classes I had in high school. So I gained experience working through concepts that I had not been exposed to before and how to study for AP tests. AP tests are like college finals." In addition, research findings also show that female students often fail to develop a science and math identity (a personal connection to science and math) because boys are more likely than girls to be encouraged to pursue those academic domains (Burke & Mattis, 2007; Perez et al., 2014). Because science and math identity is likely firmly developed by fourteen years of age, girls should be deliberately encouraged to participate and persist in these subjects in various ways prior to middle school (Archer, Dewitt, Osborne, Dillon, Willis & Wong, 2010).Sarah supported this idea stating, "early exposure (to math, science, CS/CE) is better versus in middle school when you are going through puberty and you're so worried about what everybody else thinks about you. You have to decide if you want to be nerdy, or if you want to be the cool kid."

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Recommendation 3. College faculty should implement ways that students can ask and/or respond to questions in class that protect their perceived competence, such as using "clickers." Clickers are electronic devices that allow students to indicate problems with comprehension or communicate their level of understanding anonymously. Professors would need to ask students to rent or purchase a clicker from the campus bookstore or another retail store. Professors then build questions into the class lecture and students respond to them using the clicker device (as opposed to raising their hand and speaking aloud). These questions can cover specific content such as "do you understand recursion?" or general questions such as "should I provide another example?" Students simply press the button that corresponds to the correct answer for the question posed and the professor receives real-time feedback about students understanding. The professor can make a judgment regarding further explanation of the content without any one student revealing their confusion.

Recommendation 4. College faculty should find ways to explain concepts in class that appeal to students who have less knowledge about computer science, particularly in introductory courses. Some students, such as most of the female students in this study, enter CS and CE programs with limited prior CS/CE knowledge and faculty can take steps to become aware of the variation in understanding among the class. By using an approach that emphasizes accurate assessment of prior knowledge, faculty can implement more effective teaching strategies. Additionally, faculty should consider implementing supplemental activities that students complete alongside regular

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coursework that introduce concepts in online environments that mirror real-life (e.g., Soh, Shell, Ingraham, Ramsay, & Moore, 2015).

Recommendation 5. When possible, faculty should assign student work groups such that students are not being excluded from collaborative opportunities (See Appendix G for Sample Group Evaluation Rubric). In this study, students explained that male students in particular often did not want to form groups with female students. The results in this study suggest that engagement with and in respect to peers (performance approach goals) predicts academic performance. Therefore, to promote collaboration, faculty should create groups and assign group projects (e.g., Shell, Hazley, Soh, Miller, Chiriacescu, & Ingraham, 2014). Implementing student groups could not only increase engagement but it could also lead to increased coping skills. For example, Cassy described finding a friend who became a study partner. She explained, "I was lucky enough to have an early-morning class with another student who ended up being my support system throughout various classes going forward." This engagement with a classmate was at least partly responsible for her success in the CSCE program.

Limitations

This study has several significant limitations that should be considered while accessing the importance of this research. First, the participants in this research was highly homogeneous, consisting of mostly European-American students. In fact, during phase one of the study, ethnicity was not collected due to the small number of minority students enrolled in the computer science program where the study took place. The Institutional Review Board required that we omit ethnicity due to the potential that

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minority students might be identifiable. During the qualitative phase of the study, five of the six participants were European – American students and one of the six students was from India.

This lack of diversity is due to the demographic characteristics of the computer science and computer engineering program included here. First, there were not many students who were female. There were, for example, 1,017 male students in the quantitative phase of this study but only 187 female students. I recruited students from multiple sources. I contacted the residence hall that houses computer science students who were double majoring in business, the multicultural student affairs office on campus, support groups for women students housed in the counseling center and in the department of computer science and also approaching each professor that teaches an undergraduate computer science class. However, I was unable to recruit American minority female students. This likely means that minority female enrollment was much lower than overall female enrollment during the timeframe of this study.

This research also attempted to understand student's motivation and self-regulation behavior but was limited to a cross-sectional design. Studies that follow students beginning at the first year of college until senior year or points further in their careers may uncover developmental changes or progress that this short-term study could not illuminate. Additionally, Phase one was also variable centered and perhaps a more person-centered approach such as cluster analysis might reveal adaptive processes or patterns among the participants. Finally, the small number of female students who

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participated in the second phase of this study is limiting and future studies should qualitatively query more female students.

Future Directions

Future studies should include more students from diverse backgrounds. Perhaps the qualitative data from a more diverse sample of participants would reveal other strategies that students from different ethnic, socioeconomic and cultural backgrounds may use to succeed in CS and STEM fields. It might also reveal different challenges that students have been able to overcome. For example, students from different cultures may have different family responsibilities or different levels of access to resources so it would be interesting to study resiliency in that context. Most students in this study were traditional students (18-22 years of age) so studying older students may reveal different coping mechanisms. Research should be conducted with larger amounts of female participants as well. The quantitative phase, in particular, had far fewer female than male students. In addition, it might be advantageous to conduct research investigating high performing female students in computer science who are studying at all female schools. Universities with large minority female populations, such as Bennet or Spelman Colleges, should be considered as sources for participants as well. This could provide an opportunity to compare and contrast the challenges, student implemented strategies, and teaching practices at all female versus mixed gender schools.

Future studies should also investigate and compare the characteristics of successful and unsuccessful female students' self-efficacy, ability beliefs, motivation and self-regulation. This research strategy could help provide more nuanced information

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about how students are able to be successful in demanding academic programs like computer science and computer engineering. Studies should also be undertaken to investigate the impact of task and performance goals in competitive academic settings. This research could help us better understand how this type of context may impact the constructs that we measure and the way we measure them. For example, the competitive environment of computing may mean that performance avoidance goals (not looking incompetent) may not be maladaptive. It seems that the women in this study engaged in more adaptive study behaviors in an effort to avoid being considered low skilled. This deserves closer examination. Additionally, the findings here suggested that perhaps students may also set the type and frequency of study habits they employ based on the goals they are pursuing. These strategies could change along with goals. Future studies should investigate these potential changes to uncover any subsequent impact. Lastly, future research should query faculty about the challenges and successes they have experienced educating and retaining female students in STEM programs that are highly populated by male students.

Finally, research should explore the ways that stereotype threat and learning avoidance goals relate to one another in the competitive context of computer science and computer engineering (e.g., Spencer, Steele & Quinn, 1999). In this research, female students were more likely to set learning avoidance goals, which are those goals students set to avoid being perceived as incompetent. Stereotype threat research also examines ways in which students are impacted by how others perceive their competence. Studying

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these constructs together might perhaps shed new light on ideas relevant to both goal orientation and stereotype threat theories.

Research that focuses on female students in computing fields and the ways in which they persist despite the tendency for them to leave STEM programs is an important undertaking. This study has shown that academic challenges or periodic failures are a part of the academic process and students do better when they have the tools, support and mindset to overcome those types of setbacks. Also, this study supports the inclusion of high-level math and science classes at the secondary level. Students who have little computing experience but successfully completed rigorous math and science classes may have a better chance of success in CS/CE majors than those who had no access to high-level math and science. With funding challenges and the shortage of teachers who can effectively deliver higher-level courses, studies that demonstrate the specific value of calculus and advanced placement physics, for example, are worthy of pursuing. In addition, this study demonstrated the need to include more STEM programs, particularly computer science and computer engineering, at the K-12 level beyond afterschool and community programs. When a variety of student's have access to preparatory courses we can ensure that a diverse body of students enter and persist in computer science and computer engineering programs.

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Appendix A

Proposed Informed Consent

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INFORMED CONSENT FORM

Identification of Project: Female Students Persistence in STEM Education

Participation Process: You completed an undergraduate computer science course successfully.

Purpose of the Research: This research project is designed to identify the characteristics of successful female students studying in STEM domains. The aim of this study is to better understand the relationship between successful female student's motivation, self-regulation and course grades.

Procedures: Participation in this study will consist of a focus group or an interview. The approximately 45-minute focus group or interview will be conducted in person or by an electronic group meeting platform offered free of charge by Google Hangouts ©. The online meeting format will be used only if students are unavailable to meet in person due to schedule conflicts. The focus group and interview will be audio or video taped with your permission. We will begin by asking you this general question: What factors contributed to you being successful in the computer science course(s) you have taken? Follow up questions will then be asked to probe the factors more deeply.

Risks and/or Discomforts: There are no known risks or discomforts associated with participating in this research.

Benefits: Though there are not direct benefits of participating in this study, this interview is an opportunity for you to share insights and stories about your success as a student studying in a STEM major. The data from this interview may help parents, students, teachers, policy makers, and scholars improve how they approach STEM schooling and the decisions they make regarding STEM education policy and practice.

Confidentiality: Results of the project will be reported at professional conferences and/or published in educational or domain specific journals and books. Because this work is focused on successful female students and no names will be recorded, your identity will not be evident in publications and presentations related to this research. After the immediate transcription of focus group data is complete, all audio, video and forms related to your focus group participation will be erased or otherwise discarded.

Compensation: The compensation for participating in this focus group is a one-time payment of $20.00 awarded at the conclusion of the focus group. Compensation will be mailed to you if the focus group takes place online or given to you immediately after the focus group concludes if it takes place in person.

Opportunity to Ask Questions: You have a right to ask questions about the study and have those questions answered before or during the study. You are free to contact the Co-Principal Investigators Dr. Eric Buhs at (402) 472-6948 and Melissa Patterson Hazley at (816) 908-4551 with any questions or concerns.

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- if you want to voice concerns or complaints about the research
- in the event of a research related injury

Sometimes study participants have questions or concerns about their rights. In that case, you should call the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965 for the following:

- you wish to talk to someone other than the research staff to obtain answers to questions about your rights as a research participant
- to voice concerns or complaints about the research
- to provide input concerning the research process
- in the event the study staff could not be reached,

Freedom to Withdraw: Participation in this study is voluntary. You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with your instructor, the investigators, or the University of Nebraska-Lincoln. Your decision will not result in any loss or benefits to which you are otherwise entitled. You are free to not answer any specific survey, interview, or focus group questions if you feel uncomfortable providing an honest answer.

Consent, Right to Receive a Copy

YOU ARE VOLUNTARILY MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS STUDY. BY CHECKING NEXT TO THE STATEMENTS BELOW YOU CERTIFY THAT YOU HAVE DECIDED TO PARTICIPATE AND ARE WILLING TO BE RECORDED. YOU MAY REQUEST A COPY OF THIS CONSENT FORM TO KEEP FOR YOUR OWN REFERENCE.

_____ Check if you agree to participate in this focus group.

_____ Check if you agree to be audio taped during the interview.

Signature of Participant:

_____ _____

Signature of Research Participant *Date*

Melissa Patterson Hazley, M.A., Co-Principal Investigator Cellular: (816) 908-4551

Eric Buhs, Ph.D., Co-Principal Investigator Office: (402) 472-6948

Fax: (402) 472-8319

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Appendix B

Goal Orientation

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COURSE GOALS SCALE

Students differ in what they want to get out of the courses they take. Use the scale given to rate how important achieving each of the following is for you in your **CS1 class**.

1	**2**	**3**	**4**	**5**
Very Unimportant	Somewhat Unimportant	Neither Unimportant Nor Important	Somewhat Important	Very Important

1.	1	2	3	4	5	Doing better than the other students in the class on tests and assignments.
2.	1	2	3	4	5	Learning new things that you don't know.
3.	1	2	3	4	5	Not looking stupid.
4.	1	2	3	4	5	Getting a passing grade with as little studying as possible.
5.	1	2	3	4	5	Getting a good grade in the class.
6.	1	2	3	4	5	Getting this course done even though you don't care about the content.
7.	1	2	3	4	5	Getting through the course with the least amount of time and effort.
8.	1	2	3	4	5	Getting the highest grade in the class.
9.	1	2	3	4	5	Learning new knowledge or skills in the class just for the sake of learning them.
10.	1	2	3	4	5	Doing my best on course assignments and tests.
11.	1	2	3	4	5	Getting a grade whether you remember anything beyond that or not.
12.	1	2	3	4	5	Not having to work too hard in the class.

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13. 1 2 3 4 5 Keeping others from thinking you are dumb.

14. 1 2 3 4 5 Remembering material long enough to get through the tests after which you can forget about it.

15. 1 2 3 4 5 Impressing the teacher with your performance.

16. 1 2 3 4 5 Really understanding the class material.

17. 1 2 3 4 5 Avoiding looking like you don't understand the class material.

18. 1 2 3 4 5 Getting high grades on tests and other graded assignments.

Scales for Goal Orientation

Learning/Mastery Approach – 2 9 16

Learning/Mastery Avoid – 6 11 14

Performance Approach – 1 8 15

Performance Avoid – 3 13 17

Outcome/Task Approach – 5 10 18

Work/Task Avoid – 4 7 12

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Appendix C

Student Perceptions of Classroom Knowledge-Building

(Strategic Self-Regulation)

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STUDENT PERCEPTIONS OF CLASSROOM KNOWLEDGE-BUILDING (SPOCK)

For each of the statements on this and the following page, indicate how frequently you think the activities described in each of the statements occurred in your **CS1 COURSE**. Do not consider your other courses or school in general when responding to these statements. Consider only **THIS CS1 COURSE**.

Use the following scale to make your responses:

5 - Almost always -- > Usually or always occurred: on a rare occasion it may not have occurred.

4 - Often ---------- > Occurred frequently: occurred about ¾ of the time.

3 - Sometimes ------- > Occurred about half of the time.

2 - Seldom ---------- > Did not occur often: occurred about ¼ of the time.

1 - Almost never ---- > Occurred on a very rare occaision or not at all.

****

1. _____ In this class, my classmates and I actively worked together to complete assignments.
2. _____ As I studied the topics in this class, I tried to think about how they related to the topics I was studying in other classes.
3. _____ In this class, I asked questions so that I could be sure I knew the right answers for tests.
4. _____ In this class, the instructor told us what the important information was.
5. _____ In this class, I set goals for myself which I tried to accomplish.
6. _____ In this class, I couldn't figure out how I should study the material.
7. _____ In this class, I asked questions about topics that interested me.
8. _____ In this class, my classmates and I actively worked together to help each other understand the material.
9. _____ In this class, I tried to determine the best approach for studying each assignment.
10. _____ In this class, I asked questions to satisfy my own curiosity.
11. _____ In this class, I focused on those topics that were personally meaningful to me.
12. _____ In this class, I asked questions to be clear about what the instructor wanted me to learn.
13. _____ In this class, I tried to monitor my progress when I studied.

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14. _____ In this class, when I got stuck or confused about my schoolwork, I needed someone else to figure out what I needed to do.
15. _____ In this class, I made plans for how I would study.
16. _____ In this class, I tried to examine what I was learning in depth.
17. _____ In this class, the instructor focused on getting us to learn the right answers to questions.
18. _____ As I studied a topic in this class, I tried to consider how the topic related to other things I know about.
19. _____ In this class, I relied on someone else to tell me what to do.
20. _____ When I did my work in this class, I got helpful comments about my work from other students.
21. _____ In this class, I asked questions to more fully understand the topics we were learning.
22. _____ In this class, the instructor gave us specific instructions on what we were to do.
23. _____ In this class, I asked questions so that I could find out what information the instructor thought was important.
24. _____ In this class, my classmates and I actively shared ideas.
25. _____ In this class, I tried to fully explore the new information I was learning.
26. _____ In this class, I thought about different approaches or strategies I could use for studying the assignments.
27. _____ In this class, I had difficulty determining how I should be studying the material.

SPOCK SCALES

General Self-Regulation - 5 9 13 15 26

Knowledge Building - 2 11 16 18 25

Question Asking

Low level -3 12 23

High level - 7 10 21

Lack of Regulation - 6 14 19 27

Cooperative Learning - 1 8 20 24

Teacher Directed Classroom - 4 17 22

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Appendix D

Focus Group Protocol

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Proposed Focus Group Protocol

The purpose of this focus group is to understand the characteristics of successful female students studying in STEM education areas.

General Feedback

1. What were your general experiences in the course(s).

    a. What did you like most about the computer science course that you completed?
    b. What did you like least about the computer science course that you completed?
    c. What are your thoughts about the department in general?
        a. Likes?
        b. Dislikes?
    d. What would you change about the course or the department?
    e. Why did you decide to take this course?

Goals

2. Describe the goals that you set for this course.

3. How did those goals change over the semester?

4. What impacted your ability to maintain the goals you set?

5. Looking back, what goals should you have set?

Self-Regulation

6. Describe your study habits?
    a. How often did you study?
    b. What were your study methods?
    c. How often did you study with other people?
    d. Who helped you study/learn the course material?

Coping Behaviors

7. Describe the obstacles you faced while completing this course?
    a. How did you manage stress (rigor) of this course?
    b. What failures did you experience this semester?
        i. How did you cope with those failures?
        ii. What adjustments did you make over the course of the semester?
    c. Some students left the class, how were you able to persist?
        i. Specifically, what did you do that made you successful?

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Support Systems

8. Describe the level and type of support you receive from other people as it related to being successful in this class?
    a. Moral support, academic support, emotional support, social support, etc.
    b. How have you gotten that support?
        i. Did you find support or did support find you?
    c. Describe your level of interaction/support from classmates, faculty and university staff as it relates to being successful in this class?

Prior STEM experience

9. Describe your prior experience in science, technology, engineering or mathematics courses?
    a. What courses have you taken previously?
    b. How did that impact your performance during the present course?
    c. What courses or experiences do you wish you would have had prior to enrolling in the class you just completed?
    d. How would you change your prior experiences in terms of helping you prepare for the course you just completed?

Career Aspirations

10. Describe your career aspirations?
    a. How have your career aspirations been impacted by completing this class?
    b. Do you anticipate any challenges in your STEM career?

Other

11. What else would you like to share about your experiences?
    a. What can we do to help other female students be successful in STEM education areas?

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Appendix E

Themes, Subthemes and Counted Values

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Code System	
Code System	380
Gender Effect	57
Asking Questions	9
Feeling Intimidated	14
Lack of Computer Science Experience	21
Transferable Skills	22
Programming	10
Problem Solvers	40
Collaboration	23
Study Behaviors	22
Influencers	109
The Village	40
Parents	22
Siblings	5
Peers/Classmates	13
Interest	13
Environments	16
Supportive Teachers/Faculty	14
Teaching Styles	4
Career Connections	26
Performance Goals	13
Pride in work ethic	7
Learning Goals	11
Missed Opportunities	4
Change in Goals	6
Creative Problem Solving	3
Variety of Areas in CS	3
Logical	2

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Appendix F

Course and Semester Listings

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Most Numerous Majors

Computer Science	357
Mechanical Engineering	208
Computer Engineering	158
Civil Engineering	199
Electrical Engineering	89

CSCE Classes in the Sample

		Frequency	Percent	Times in Sample
	CSCE 155E (JAVA)	147	10.4	4
	CSCE 155E (C)	191	13.5	4
	CSCE 155N (Matlab)	292	20.7	5
	CSCE 155T	1	.1	1
	RAIK 183H	80	5.7	4
	CSCE 322	25	1.8	2
	CSCE 428/828	13	.9	1
	ARTP 189H	32	2.3	2
	CSCE 230 (Computer Organization)	27	1.9	1
	CSCE 478/878 (Introductions to Fundamentals of Machine learning)	21	1.5	1
	CSCE 310 (Data Structure and Algorithms)	13	.9	1
	CSCE 310H (Honors Data Structure and Algorithms)	911	.8	1
	CSCE 471/871 (Introduction to Bioinformatics)	7	.5	1
	CSCE 475 (Multiagent Systems)	6	.4	1
	Total	866	61.4	
Missing	System	544	38.6	
Total		1410	100.0	

*See page 47 for discussion of 155 suite of freshman classes (e.g., 155E, 155N.

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Appendix G

Sample Group Evaluation Rubric

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Use the following form to evaluate each member of your group, including yourself. Evaluate each statement as it applies to the members of your group, assigning them a score between 1 and 5. A score of 1 indicates "Strongly Disagree" with the statement as it applies to that student, whereas a score of 5 indicates "Strongly Agree." Your evaluation should be honest.

Category	You:	Student 2 (name):	Student 3 (name):	Student 4 (name):
Came prepared and ready to participate in all group meetings. (1-5)				
Offered creative suggestions for the development of group material. (1-5)				
Dealt effectively with internal group conflicts. (1-5)				
Performed work which was very useful and contributed significantly to the final project. (1-5)				
Focused on the task at hand. (1-5)				
Finally, in two or three sentences, please sum up this student's most valuable contribution to your group. Use reverse side if necessary.				

**This rubric created by Sean Trundle; University of Nebraska, Lincoln, Department of History*

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