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Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Analysis

by

Scott Ragsdale

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in
Computing Technology in Education

Graduate School of Computer and Information Sciences
Nova Southeastern University

2013

An Abstract of a Dissertation Submitted to Nova Southeastern University
in Partial Fulfillment of the Degree of Doctor of Philosophy

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Scott Ragsdale

April, 2013

The computing profession in the United States would benefit from an increasingly diverse workforce, specifically a larger female presence, because a more gender-balanced workforce would likely result in better technological solutions to difficulties in many areas of American life. However, to achieve this balance, more women with a solid educational foundation in computing need to enter the computing workplace. Yet a common problem is most colleges and universities offering computer-related degrees have found it challenging to attract females to their programs. Also, the women who begin a computing major have shown a higher tendency than men to leave the major. The combination of these factors has resulted in a low percentage of females graduating with a computing degree, providing one plausible explanation for the current gender imbalance in the computing profession.

It is readily apparent that female enrollment and retention must be improved to increase female graduation percentages. Although recruiting women into computing and keeping them in it has been problematic, there are some who decide to pursue a computer-related degree and successfully finish. The study focused on this special group of women who provided their insight into the pursuit and completion of an undergraduate computing degree. It is hoped that the knowledge acquired from this research will inspire and encourage more women to consider the field of computing and to seek an education in it. Also, the information gathered in this study may prove valuable to recruiters, professors, and administrators in computing academia. Recruiters will have a better awareness of the factors that direct women toward computing, which may lead to better recruitment strategies. Having a better awareness of the factors that contribute to persistence will provide professors and administrators with information that can help create better methods of encouraging females to continue rather than leave. The investigation used a sequential explanatory methodology to explore how a woman determined to pursue an undergraduate computing major and to persevere within it until attaining a degree.

Acknowledgements

First, I want to express my gratefulness to God for being a never-ending source of wisdom, strength, and encouragement to me, and for placing in my path many wonderful people who helped me complete an academic goal I never could have achieved alone.

To my dissertation committee chairman, Dr. Steve Terrell, I am thankful for your encouragement, advice, and confidence in me. Your guidance along this dissertation path has been a tremendous blessing. To committee member Dr. Gertrude Abramson, thank you for motivating me to do my absolute best throughout the doctoral program and dissertation. To committee member Dr. Nicholas Ditirro, thank you for your helpful feedback on the many drafts I submitted during this process. I am honored that each of you would be on my committee. Words cannot express my deepest gratitude for the time and effort spent by this committee in helping me pursue and complete this work.

Thank you to Harding University for your financial and personal support in this endeavor. A special thanks to the following members of the Harding family: President David Burks, Dr. Larry Long, Dr. Marty Spears, Dr. Travis Thompson and members of the executive committee for approving my pursuit of a doctoral degree, Dr. Beckie Weaver for granting IRB approval in a timely manner, Dr. Michael "Coach" Claxton for his proofreading and writing advice, my colleagues in the Computer Science Department — Dr. Tim Baird, Dr. Steve Baber, Dr. Frank McCown, Dr. Dana Steil and soon-to-be Dr. Gabriel Foust — for their helpful ideas and support, to Tina Gould and the testing office for granting me the resources to create and implement the survey, and to the library staff for your assistance in finding material and providing me a place to work.

To the 210 women who participated in this study, thank you for your time, input, and interest. The positive comments I received from some of you helped convince me that this work was important and relevant to the field of computing.

To my beautiful wife Janis, thank you for showing your faith in me that always carried me through times of doubt, discouragement, and frustration. To my remarkable children Brooke and Brandon, thanks for always believing I could "get it done!" To Dad and Mom, thank you for exemplifying so many noble virtues, especially commitment and perseverance, and teaching these to me. Without these two traits, this dissertation would have been impossible to complete. Dad, even though you no longer walk on this planet, I know you would be extremely proud of me. To my older and only sibling Randy, my hero, thank you for your ability to continually encourage me to keep "pressing on."

To my many former and current students, friends, and colleagues, thank you for your help — whether it was helping me find participants for the study, giving me ideas, or simply asking me how things were going. Your help and concern was invaluable.

In closing, I would like to dedicate this dissertation to the four men, who in their own individual way, have inspired me to be a better person and teacher. To Dr. Tim Baird, Dr. Dean Priest, Dr. Steve Smith, and Dr. Travis Thompson, thank you for being a wonderful blessing to my life.

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Chapter 1

Introduction

Background

Undergraduate students interested in pursuing the study of computers will encounter many kinds of computing degree programs, and the variety of names used for the programs is even broader (Joint Task Force for Computing Curricula, 2005). Snyder and Willow (2010, p. 404) list 21 different types of computer-related bachelor degrees conferred in the years 2007-2008, with more than 60% of degrees awarded either to computer science or information science (Table 1). Of particular interest to this study is the one common characteristic found within each computing program listed by Snyder and Willow ─ *a much larger percentage of males receive degrees as compared to females.*

For many years, women have been strongly underrepresented in computing academia and continue to be. Researchers have studied the female underrepresentation phenomenon for more than two decades, seeking reasons why females seldom enroll in post-secondary computing study. Explanations range from placing the blame on high schools for offering few to no computer-science courses (Buzzetto-More, Ukoha, & Rustagi, 2010), to a belief that computing is a male domain discouraging many females from entering the discipline (Margolis & Fisher, 2002; Papastergiou, 2008). Other research proposes that computing is perceived to be an antisocial discipline, which is non-attractive to females (Ali, 2009), or that women simply cannot comprehend how

computer science can be applied to help solve societal problems (Sainz & Lopez-Saez, 2010). Disinterest among women in computer science is nothing new. Universities, as well as government agencies and technology companies, have contributed large sums of money (estimated in the tens of millions) to find ways to attract more women for almost a decade but success has been insufficient (Gose, 2012).

Table 1: Bachelor's degrees conferred in computer and information sciences by gender (2007-08)

Type of Degree	Male	Female	% Female
Computer and information sciences and support services (total)	**31,694**	**6,782**	**18%**
1) Computer and information sciences, general	8,815	1,638	16%
2) Information technology	2,652	706	21%
3) Computer and information sciences, other	166	32	16%
4) Computer programming/programming, general	454	68	13%
5) Computer programming, specific applications	12	2	14%
6) Computer programming, other	148	26	15%
7) Data processing and data processing technology/technician	109	25	19%
8) Information science/studies	3,869	1,205	24%
9) Computer systems analysis/analyst	704	190	21%
10) Computer science	6,918	941	12%
11) Web page, digital/multimedia and information resouces design	632	295	32%
12) Data modeling/warehousing and database administration	7	5	42%
13) Computer graphics	1,065	277	21%
14) Computer software and media applications, other	220	46	17%
15) Networking and telecommunications	1,393	247	15%
16) System administration/administrator	127	15	11%
17) LAN/WAN management/manager	163	19	10%
18) Computer and information systems security	1,086	188	15%
19) Web multimedia management and webmaster	2,208	591	21%
20) Computer/Information tech, services admin and management	319	126	28%
21) Computer and information sciences and support services	627	140	18%

Note: Data taken from *Digest of Education Statistics* (Snyder & Willow, 2010)

There are two primary concerns affecting female participation in undergraduate computing academia. The first concern is a declining enrollment trend. A decade ago, Margolis and Fisher (2002) co-authored a book that highlighted the lack of female presence in college computer-science programs, observing that women were infrequently enrolling in these programs to learn how to invent, design and construct computer technology, even though women use computer technology as much as men. Four years later in a 2006 interview, Margolis stated that female participation in computer-science study was getting worse (Carlson, 2006). Statistics provided by Varma (2009) support Margolis's claim. In 2000, the year when Margolis and Fisher were concluding their initial research, 1.9% of women at U.S. institutions indicated computer science as their probable collegiate major. By the year 2006, a span of seven years, the percentage was 0.4%, which represented a 79% decrease in women intending to study computer science. Additional evidence suggesting that the female underrepresentation phenomenon is becoming worse is furnished by Lenox, Woratschek, and Davis (2008), who note that the number of females entering computer-science programs has continuously declined since 1982, the peak year for female enrollment.

The second concern explaining a diminishing female presence in computing majors is attrition. After examining several research studies on female retention in undergraduate computing programs, Cohoon and Aspray (2006) conclude that females quit a computer major at a higher rate than males. An awareness of the low enrollment and high attrition quandary is critical when investigating why there are few female computing graduates.

Problem Statement

The U.S. workforce would benefit if undergraduate computing programs were more gender-balanced. Many computer majors will enter the information technology (IT) business sector, and an equitable male-to-female distribution of graduates is especially helpful to IT because it provides a uniform proportion of competent, diverse talent, a necessity for IT businesses (Cohoon & Aspray, 2006; Ramsey & McCorduck, 2005; Simard, 2007). Another argument favoring a balanced gender distribution in computer-related programs is presented by Paloheimo and Stenman (2006), who examined the climate of introductory computer-science classrooms and found that a typical computer-science classroom gender distribution (mostly male) lowered the comfort level of all students. Students were less willing to collaborate on problem-solving, resulting in underachievement, especially among weaker male students. Also, female average performance was significantly higher when placed in an even-gendered group when compared with females placed in a mostly male group. The study suggests that both male and female computer-science students would profit from a gender-balanced classroom.

Currently, however, undergraduate computer-related programs are not gender-balanced; they are male-dominated, and graduation percentages by gender confirm the inequity. As of 2008, 82% of computing degree recipients were male and only 18% were female (Snyder & Willow, 2010).

Female underrepresentation in computing has been and remains a complex phenomenon to discern (Cohoon & Aspray, 2006). For many years, extensive research

efforts have attempted to discover reasons why continuing numbers of females decide not to enroll, persist, and eventually graduate with a computer-related degree. The majority of research on the issue has focused on the negative characteristics of the problem. In other words, investigations have explored why women do not choose to study computing in college, why they leave these programs at higher rates than men, and why the number of female degree completers continues to decline. Research has seldom focused on the positive issues of the underrepresentation problem, such as discovering causes of success for female computing students (Dee, Petrie, Boyle and Pau, 2009). Attaining a degree in the field would certainly be considered a successful outcome for a female. The insights provided from female computing graduates could provide critical knowledge that could help persuade more females to consider a computer-related major. Additionally, their responses could encourage institutions to reconsider current recruitment strategies of females into a computer major, and motivate administrators and professors to be proactive and intentional in encouraging females to persevere and graduate.

Dissertation Goal

The primary goal of the dissertation research was to acquire a better understanding, from the perspective of a female computing graduate, of how a woman decided to pursue a computing major and persevered until degree completion. Singh, Allen, Scheckler, and Darlington (2007) support this goal by asserting that a gender-specific theory is needed that reevaluates the experiences of women in computing and that can direct future research on their enrollment and persistence behaviors in computer-related majors. This study searched for reasons causing these behaviors.

Secondary goals of the research were:

1. To provide information that can help develop more effective strategies in the recruitment of females to computing.

2. To inform professors and administrators in computing academia of the factors that help females persevere so they can be more active in promoting persistence.

3. To encourage and inspire capable females to consider computing as a viable academic option because their presence is needed, and because it is a discipline where they can find enjoyment, success, and fulfillment.

Research Questions

This study sought answers to eight research questions that centered on obtaining a better understanding of the factors involved in helping a female determine to start and finish an undergraduate computing degree program. Females who earned an undergraduate computing degree supplied responses leading to answers for the following:

1. What percentage took a programming course before pursuing a computing major, and if so, when was it taken and what was the enjoyment level?

2. Before beginning a computing major, what was the level of math skill and enjoyment, and was math a factor in pursuing computing?

3. At what time did an interest or fascination in computers first occur, and at what time did the thought of pursuing a computing education occur?

4. What percentage understood what they would be learning in their computing major before enrolling?

5. What percentage was confident in their ability to excel in the computing major before enrolling, and for those not confident, why did they choose to pursue computing?

6. What extrinsic, intrinsic, and other factors were most important in deciding to pursue computing study?

7. Did the academic, social, and cultural atmosphere of computing make perseverance difficult?

8. What factors were most important in encouraging persistence until degree-completion?

Problem Significance

The lack of female presence in computing professions is a significant problem, and the continual decline of women graduates in computer-related degrees exacerbates the dilemma. Becerra-Fernandez, Elam and Clemmons (2010) report a growing concern in the IT sector that there will not be a sufficient supply of computing professionals to meet future demand. Reversing the decline can provide at least three advantages. First, increasing the number of women graduates in computing brings an increase in the total number of potentially qualified workers in IT, a driving force of the U.S. economy (Cohoon & Aspray, 2006). Second, a more gender-balanced IT workforce will promote better innovations and product solutions (Ramsey & McCorduck, 2005). Third, IT businesses are looking for competent workers who also possess strong leadership and communications skills that can build more effective collaborative networks to drive innovative solutions to problems. Research suggests that women, as compared to men, have a higher-level of the leadership and communication skills that now define an IT worker (Simard, 2007).

Barriers and Issues

Two factors complicated this research. The first obstacle was locating female computing graduates. Since this population was low in quantity, a considerable amount of time and effort was expended to find a sufficient number of females from this population to conduct a study that can be generalized. The second difficulty was the time involved in carrying out a two-phase, sequential explanatory study, which will be discussed in further detail in chapter 3.

Assumptions

1. The respondents in the study provided truthful answers to the questions and statements posed.
2. The respondents were able to recall accurately events, attitudes and feelings that happened in the past.

Definition of Terms

Attrition, when used in an academic setting, refers to the dropout dilemma from a major field of study. It is most often used in conjunction with the rate of dropout (i.e. attrition rate).

Classroom climate is a term used to measure different aspects within a classroom such as: 1) organization of the classroom, 2) faculty attitudes toward student achievement, 3) student attitudes toward peers, 4) degree of democracy within the classroom, 5) acceptance of diversity, 6) autonomy of the teacher, 7) competitiveness among the students, and 8) consistency of interpretation of rule infractions and their consequences (Classroom Climate, 2006).

Computer-related major is used to describe a post-secondary major that the *National Center of Education Statistics* lists under the heading of computer and information sciences in *The Digest of Education Statistics* (Snyder & Willow, 2010) or is a major within the realm of the discipline of computing.

Computer science (CS) is one of the most common and well-known academic fields within the discipline of computing and produces the vast majority of computing majors. It blends science, engineering, and mathematics to study algorithmic processes that describe and transform information through theory, analysis, design, efficiency, implementation, and application (Denning, 2005).

Computing generally means any goal-oriented activity that requires, benefits from, or creates computers, and the list of possible activities is vast. Computing is considered to be not only a profession but also a discipline, and a student wishing to work in the computing profession typically earns a bachelor's degree in one of the computing disciplines (Joint Task Force for Computing Curricula, 2005).

Extrinsic motivation causes a person to engage in an activity as a means to some end. Some example end results for engaging a task may be a reward, recognition, the opportunity to work on another activity, or punishment avoidance (Schunk, 2008, p. 502; Ryan & Deci, 2000a).

Gender-balance is achieved in a mixed male-female group where the ratio ranges from 60:40 to 50:50 (Frieze, 2007).

Intrinsic motivation causes a person to engage in an activity as an end in itself because of the pleasure and enjoyment the task brings (Schunk, 2008, p. 502, Ryan & Deci, 2000a).

Information technology is the integration of computers, databases and communication networks to efficiently aid organizations, markets and educational institutions in their daily operations (Lucas, 1999, p. 5 – 8).

A *persistent* person refuses to give up or let go, endures, exists, or remains in the same state for an indefinitely long time (Persistent, 2011).

Underrepresentation occurs when a group is represented in numbers, or in a proportion, that is less than statistically expected or warranted (Underrepresentation, 1996-2011).

Summary

The computing profession in the Unites States would benefit from improved diversity in its workforce, specifically a larger female presence because a more gender-balanced workforce would likely result in better technological solutions to problems facing America (Ramsey & McCorduck, 2005). However, to achieve this balance, more females with a solid educational foundation in computer science need to enter the computing workplace. This pool of women, as shown by the number of females graduating with a computer-science degree, has been and continues to be alarmingly low (Singh, et al., 2007; Zweben, 2012). To further assist those involved in the research of female underrepresentation, especially those investigating the problem within the framework of an undergraduate computing major, this dissertation study presents a better understanding of the factors directing a female to pursue and graduate with a degree in the field. Insights were provided by women who possess a computer-related degree.

Chapter 2
Literature Review

Introduction

Female underrepresentation in undergraduate computing programs in the United States has been a puzzling and perplexing problem to comprehend (Cohoon & Aspray, 2006), and proof of the misunderstanding is demonstrated by the inability to either stabilize or increase female graduation rates. To provide a foundation and justification for the dissertation study, it is necessary to gain a more comprehensive appreciation of the pivotal issues from the literature. It should be noted that much of the literature associated with computing academia references the specific computing field of computer science, one of the most common computing majors (Snyder & Willow, 2010). As a consequence, many of the studies highlighted in this review of the literature are directly related to computer science.

Eight major areas directly related to this study are reviewed in this chapter. These areas include: 1) the continual decline of female graduates in computing, 2) why female underrepresentation is a critical problem, 3) reasons for the female underrepresentation dilemma, 4) what attracts females to computing, 5) why females choose to leave computing once enrolled, 6) the reasons why some women persist in a computer-related major, 7) the importance of intrinsic and extrinsic motivation in understanding behavior, and 8) the need to view the problem using a different approach.

Female Graduation Rates in Computing

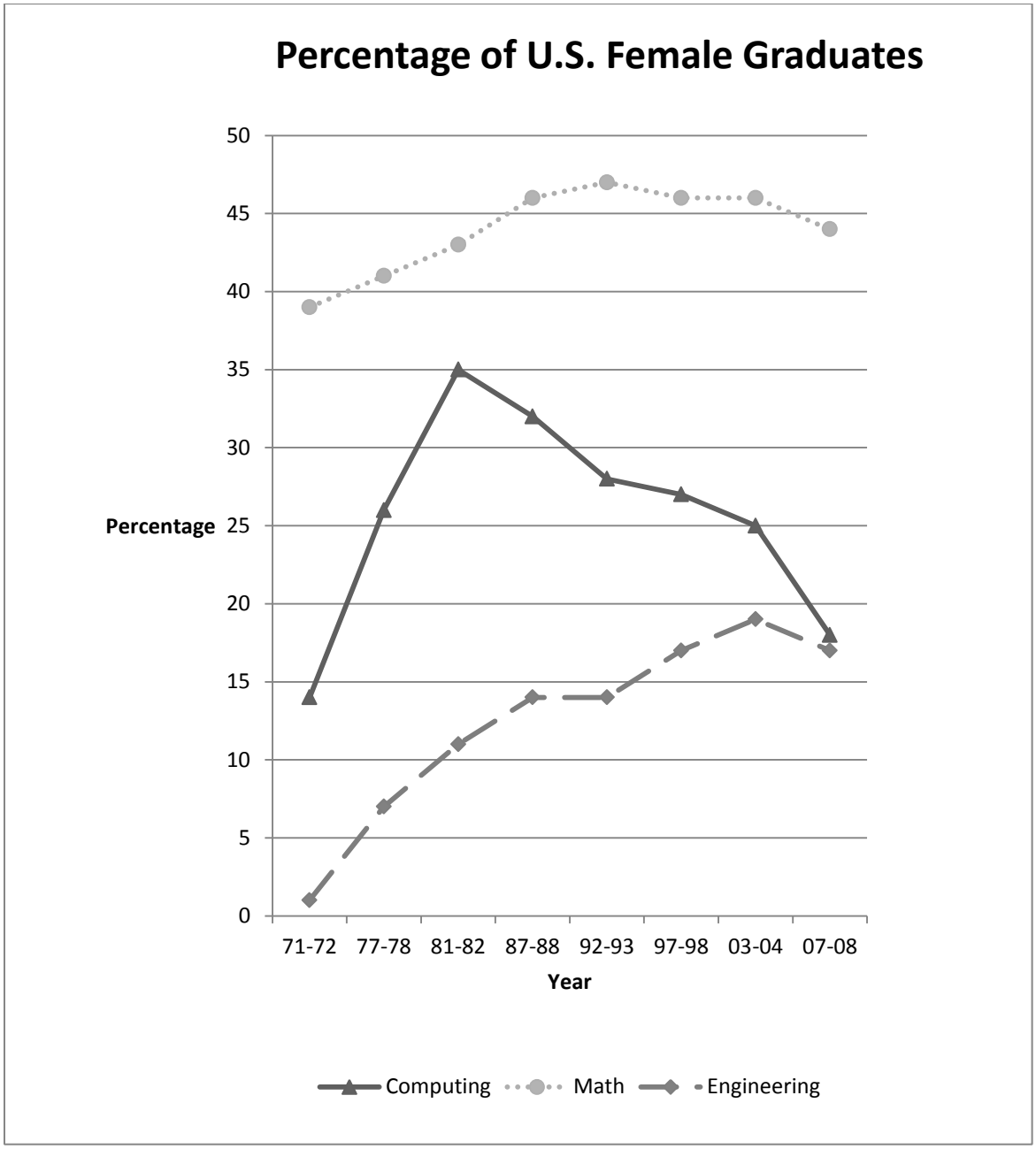
In the United States, two fields of academic study related to computing — mathematics and engineering — have experienced sustained or increased percentages of female graduates since the early 1970's. Computing, on the other hand, after peaking in the early 1980's, has witnessed a steady percentage decline of women who graduate with a degree. The line graph in Figure 1 shows U.S. female graduation percentages and highlights three trends: 1) a declining number of computing degrees for the past 30 years, 2) the fairly constant rate in mathematics degrees for the past 40 years, and 3) a steady increase in engineering degrees since the early 1970's.

The 2010-2011 Taulbee Survey provides supporting evidence from the field of computer science by reporting that female graduation percentages are continuing to wane. In 2010-2011, only 11.7% of computer science degrees were awarded to women, while the year before, 2009-2010, 13.8% of degrees went to women (Zweben, 2012). Incoming freshmen levels can help predict the number of bachelor degrees awarded four to five years later. In computing, this translates to a continued low percentage of degrees being awarded to women because of the ongoing failure to significantly increase female enrollment (Varma, 2009).

This problem is not isolated to the United States. The countries of Spain (Sainz & Lopez-Saez, 2010), Greece (Papastergiou, 2008), and Israel (Gal-Ezer, Vilner, & Zur, 2008) have also experienced reduced female computer-science enrollments, resulting in lower numbers of female graduates. With the data clearly illustrating that computer-science graduates are predominately male, the question might be raised "Does this

condition necessarily present a substantial problem?" The next section will address this matter.

Figure 1: Female graduation percentages in the fields of Computing, Mathematics and Engineering.



Note. Data obtained from *Digest of Education Statistics* (selected years between 1971 – 2008).

Female Underrepresentation Presents a Dilemma

Ashcraft and Blithe (2009) report that computing professions are growing fast, and the U.S. department of Labor predicts that by the year 2018, there will be more than 1.4 million new computing jobs available if growth and replacement are considered. Yet interest in computer education has significantly declined over the first decade of the 21st century. The number of students indicating computing and information sciences as their intended major when registering for the SAT offer proof of the interest downfall. In 2000, 64,390 college-bound students indicated computer and information science as their predicted major. In 2010, fewer than half this number, 31,164 designated this major (The College Board, 2000; The College Board, 2010). If the current level of interest does not show a significant increase soon, the industry will be able to fill only half of the projected available jobs (Ashcraft & Blithe, 2009). There is a growing concern that the supply of qualified people who are capable of handling the complexities of information technology will not meet future demand. One obvious way to increase the supply of competent workers is to graduate more women educated in the practice and theoretical perspectives of computing that will lead to effective problem solving (Beaubouef & McDowell, 2008; Becerra-Fernandez et al., 2010).

The Defense Advanced Research Projects Agency (DARPA), a branch of the United States Department of Defense, has especially grave concerns about the shortage of computer scientists. This agency is responsible for the development of new technology for the military and is worried that in the near future, there will not be enough trained professionals to maintain existing systems and develop new ones. DARPA is calling on colleges and universities to take drastic action to reverse the trend of falling numbers of

computer-science majors so that the agency can continue to build innovative and often radically new technologies, which can only be developed by well-educated and qualified people (Homeland Security Newswire, 2010).

Singh, et al. (2007) emphasize that the underrepresentation of women in computing at the post-secondary education level is a major national concern because the U.S. is facing intense competition from other countries in developing innovative technological solutions to problems. It is vital to the economic health and national security interests of the U.S. to have enough well-educated and diverse groups of people who can lead the way in developing innovations that will help continue our global, competitive edge in information technology (IT). It becomes obvious that well-educated computer professionals are in high demand now and will continue to be for many years to come. There need to be more women included in this group. Ramsey and McCorduck (2005) state that more women in IT can foster better innovations because diverse groups, rather than homogeneous groups, create better solutions to problems.

In a study of 100 teams scattered across 21 companies in 17 countries, researchers found that teams that were gender-balanced, as compared to teams with other proportions, demonstrated the most innovative potential. Innovative potential in this study was defined as the ability to "think outside the box," be creative, and to experiment. Interestingly, the study found that a 60/40 female-to-male ratio was the optimum split that created the highest self-confidence level for members within a team. Member self-confidence was found to be critical for teams to develop innovative solutions (Gratton, Kelan, Voigt, Walker, & Wolfram, 2007). Herring (2009), after analyzing data from a sample of for-profit businesses, found that gender diversity had a

positive, significant impact on key business functions. Specifically, gender-diverse businesses experienced increased sales revenue, larger customer-base and improved profitability. The positive outcomes attributed to diversity likely came from the growth and innovation that occur when people from different backgrounds work together and capitalize on their differences to arrive at better solutions. In a study examining the impact of gender diversity on financial performance of information technology firms, Catalyst (2004) found that senior management teams with a high representation of women had a higher return-on-equity than those with a low representation.

Sevo (2005) provides additional and compelling reasons why female underrepresentation in computing is a concern: 1) social justice – women should have equal access to any field, 2) national competitiveness – our educational system is not producing a workforce needed to maintain a global leadership position in IT, and 3) diversity in education – fewer women educated in computing results in fewer female computing professors, which hinders the diversity needed to provide a quality computing education.

Reasons for Female Underrepresentation in Computing Academia

Given the aforementioned arguments, it is important that computer-related programs exercise a pronounced effort in the recruiting, retaining and graduating of females. However, attracting women to the computing field has been and continues to be difficult.

Research provides several reasons for female disinterest in computer-science and related fields. Trauth, Quesenberry and Morgan (2004) indicate these reasons can be

explained by the following theories: 1) essentialist theory, which asserts that inherent biological variations exist between genders, and these can serve to explain the differences between genders in regard to computing engagement, 2) socio-constructivist theory, which contends that society shapes computing as "male work," thus placing it outside the domain of women, and 3) individual difference theory, which suggests that both biology and socio-cultural experiences combine at the individual level to lead a woman to or from computing.

There exist other research-supported factors that contribute to the female underrepresentation phenomenon. The factors appearing most frequently in the literature are: 1) deficiency in knowledge and skill due to high schools offering few to no computing courses, 2) lack of information about the field of computing and career opportunities, 3) lack of encouragement from significant others (i.e., teachers, parents, and friends) to pursue a computing education, 4) perception of the computing discipline as being antisocial and populated by antisocial (i.e., "geeks" and "nerds") people, 5) lower self-confidence, as compared with males, in computing ability, 6) belief that computing is boring, 7) failure to comprehend the relevance of computer science, and 8) perception of computing as a masculine field. Each of these factors merits detailed consideration below.

Because of a growing concern in the declining number of students pursuing computer science (CS) in college, Carter (2006) surveyed 836 students from nine different high schools who possessed an aptitude favorable for computer-science study because they were enrolled in either a Calculus or Pre-Calculus class. The survey showed that these students were severely lacking in computer training, particularly

courses such as computer programming. It was found that only 8% of the students had any formal computer-science course outside of computer applications (e.g., - word processing, PowerPoint). Further research has confirmed the problem. Varma (2009), in interviews with 150 computer science or engineering students, discovered that 86% of those interviewed believed they were either partially prepared for college computer-science study or were not prepared at all. The major reason cited was a "deficient computer-science curriculum" in high school. The reason for believing they were partially prepared was basically due to math courses taken, not CS courses. Various quotations reflect student perceptions that "computer science was basically a word-processing class," "the only thing we did on computers was PowerPoint," "we did not learn programming in high school," and "there were no computer-science courses." Only 14% of the students felt that their high-school educational experience had prepared them well because of programming and mathematics courses. Not surprisingly, the large majority of well-prepared students were male (i.e., 67% male to 33% female). Buzzetto-More, Ukoha, & Rustagi (2010) asked female computer-science students at the University of Maryland Eastern-Shore about their preparedness for studying computer-science. While 57% percent indicated they had studied computing, only 30% had any formal computer-science course such as computer programming.

Many college-bound students have a general unawareness and various misconceptions of the nature and activities of computer science, and, as a result, they do not consider computer science as a potential major field of study leading to a satisfying profession. Career opportunities in the field are numerous and available in virtually every segment of society, such as business, military, communications, or health-care. Aspects

of computing intersect people's lives daily, but this fact is rarely communicated, resulting in an uninformed student population (Beaubouef & McDowell, 2008). Kahle and Schmidt (2004) found that most women had insufficient knowledge about computer science before taking courses in the field and concluded that this lack of knowledge is the most important reason why women are not enrolling in computer science because they have no chance to make a determination if this major is the right pursuit for them or not. In a study surveying 358 high school students about their intentions and motivations to study computer science in college, Papastergiou (2008) discovered that males had a much broader view of the field than females, who believed that computer science consisted only of hardware and programming. Powell (2008) found that beginning female computer-science majors believed that computer science could lead to a successful job upon graduation but could not visualize or describe the job. This lack of knowledge about the computing field, Powell concluded, significantly affected their attitude and persistence because their first college experience with computing was limited to programming. Therefore, they assumed that a career in computing involved only programming and debugging a machine. Townsend, Menzel, and Siek (2007) report that many females believe that a career in computing will result in the rest of their lives being spent "programming in a cubicle," thereby preventing them from working with or helping people. Carter (2006) asked high school students what computer-science students learned, and 80% responded that they had no idea. For those who gave a response, most believed that programming was the major topic taught and learned. It is evident that the field of computer science is misunderstood by many students, making enrollment a less-attractive option and persistence, if enrolled, more difficult.

The lack of encouragement that women receive to pursue studies and careers in computing is believed to be another major reason for female underrepresentation. According to Cohoon (2002), parents and friends rarely encourage women to choose and continue in computer science. The low number who choose to study computer science in college will typically suffer from a lack of peer support because there are few other women in the major from whom they can seek help and encouragement. Female computer-science students may also be considered an oddity within the CS major by fellow majors and students in other majors. At times, CS faculty discourage females inside and outside the classroom by communicating male viewpoints and behaviors that are detrimental to the female psyche. Kahle and Schmidt (2004) agree that most women are not encouraged by significant people in their lives to pursue computing careers, resulting in lesser female participation. In extensive interviews with 150 undergraduate CS students from seven different institutions, Varma (2009) found that high-school teachers seldom encouraged women toward computing careers, whereas males indicated that high-school teacher influence was a major factor leading them into computing. Ayda and Kaiser (2005) reviewed and synthesized literature from the fields of math, science, engineering, education, and sociology to understand the early determinants influencing a female to pursue a career in IT (i.e., a broad term used in this study that combines the fields of computer information systems , management information systems, and computer science). A major finding in their literature review was that high-school teachers, as well as counselors, often provided females with meager to no direction toward a computing career. Providing encouragement is viewed as vital to persuading more women to enter computing study, but the review also discovered that female

participation was rarely encouraged. Teague (2002) interviewed 15 female computing professionals to discover reasons for females entering the computing field. Seven of the interviewees — almost half — mentioned the importance of encouragement from family, friends, and teachers in making their career choice.

Because the computing field and computing professionals are commonly tagged with a perception of being antisocial, many women are discouraged from entering computer-related majors. Mikesell and Rinard (2011) state that females are discouraged from considering CS in college because of the "geek" image associated with it. Movies typically depict a computer-science character as a nerd, a highly intelligent person possessed with bad hygiene, social ineptitude, and physical unattractiveness. Whether or not these images accurately portray reality, the fact remains that this image is a common perception, and therefore, it is not exactly an image that attracts women to the field. Carlson (2006) interviewed Claudia Morrell, a researcher investigating attitudes and influences of women and younger females in computing, and she made the following statement: "Unfortunately, computer fields have a geeky image, and girls in particular don't want to be perceived as being geeks and nerds." Morrell agrees that the media has done a good job in creating the image of a computer scientist as "a brilliant but socially inept mumbler who could use a few tips on hairstyles and clothes." A large sample of high school students believed that both the computing field and computer scientists themselves are socially deficient. Carter (2006) found that two of the strongest influences against CS for females, as indicated by 839 high-school students, was a lack of desire to sit in front of a computer all-day and a perception that CS was not a people-oriented major. Harris, Cushman, Kruck, and Anderson (2009) investigated attitudes

towards computing of incoming freshmen, and 70% of the females believed that computing involved working with machines instead of people. Sainz and Lopez-Saez (2010) obtained data from 550 high-school students on computer attitudes and discovered that women believe that computers and technology are incompatible with social skills, which females see as important to achieve proper professional and personal development. The women in this study also viewed computer scientists as freaks, geeks, and socially isolated. High-school teachers, as well, indicate that a major reason more women do not enroll in high-school computer courses is the geeky image portrayed by these courses, and they do not want to be associated with that image or with the people who promote it (Margolis and Fisher, 2002).

Studies of females enrolled in college CS courses provide additional proof that computer science projects a non-social atmosphere. Interviews with first-year female CS majors at the University of Pennsylvania indicated that social isolation was a reality in their courses and that this isolation weakened their resolve to continue in the major (Powell, 2008). Beyer, DeKeuster, Walter, Colar, and Holcomb (2005) conducted a study to see if beginning CS students' attitudes would change from one semester to the next. Interestingly, female students became less likely to believe that computer-science majors were nerdy, suggesting that preconceptions may be changeable. However, females also became more convinced that CS does not promote social activity and that CS people do not enjoy being around others.

Further evidence of the widely held perception of computing containing non-social characteristics is provided by Singh et al. (2007), who performed a meta-analysis of 44 research studies to determine factors influencing a woman's decision to enter and

stay in computer-related majors. They concluded that the geek stereotype within CS was a major contributor to steering women away from computing. Burge and Suarez (2005) also conducted a literature review of factors affecting women in the computing sciences and determined that women are turned off by the image of a computer scientist as being uninteresting and nerdy.

It should be noted that perception does not necessarily equal reality. Margolis and Fisher (2002) coined the term "geek mythology," which contends that the view of a computer-science student as equal to a geek is mostly a myth. A geek is described as a person "highly intelligent and myopically focused on computers who neglects everything else." A large majority of the students interviewed by Margolis and Fisher strongly asserted that the geek definition did not apply to them, and that they had a broad range of interests in other areas. Interestingly, the term *geek* can be a complimentary term in some areas. In the United States, the connotation of the word *geek* is generally insulting to females, and therefore, a majority of females do not pursue CS to avoid this label. However, in China, the connotation is the exact opposite. The word for *geek* is always used in a positive context and is generally said and received as a complement (Trauth, Quesenberry, & Huang, 2006).

In measures of academic ability and performance in computer-science classrooms, many studies indicate that males and females exhibit equal success rates. However, the literature overwhelmingly shows that females have a low confidence level and low assessment of computing ability as compared with males, which serves as a major disincentive in a woman's intention to study computing and persist in it (Singh et al., 2007). Papastergiou (2008) asserts that self-efficacy is positively related to a female's

intention to study CS. Self-efficacy is a person's judgment about his or her ability to carry out a goal. High self-efficacy is critical in problem-solving, a key aspect of computer science, because it can promote usage of effective cognitive strategies, a higher amount of effort exerted, and more positive attitudes in the face of obstacles. Beckwith, Burner, Grigoreanu, and Wiedenbeck (2006) discovered a significantly lower self-efficacy attribute in females as compared to males when using computer software as an aid in solving a problem.

Moorman and Johnson (2003) provide support for the belief that low confidence levels in computer skills are prevalent among high-school age females. In a survey of 941American high-school students taking advanced placement Calculus and/or computer science, females consistently undervalued their skills, especially when comparing them to males. Despite equal or better academic performance, females communicated a belief that males are naturally better at mathematics and computing. Statistically, 65.2% of men claimed to be more advanced in computing skills than women, while only 19.2% of females claimed to have a higher skill level than men.

Three studies indicate that once a female enters college, feelings of inadequate computing skills persist. Beyer, Rynes, Perrault, Hay, and Haller (2003) received questionnaire responses from students in introductory computer-science courses. In general, those with higher ACT scores had higher confidence in computing ability. Not surprisingly, however, there was a significant gender difference. Women had less confidence than males, even when controlling for ACT scores. In fact, male non-CS majors had a higher confidence level than female CS majors. In a study of first-year, female retention in computer science at the University of Pennsylvania, Powell (2008)

learned that a majority of women perceived that men were more knowledgeable in computer science than they, and this perception caused several to lose confidence in their ability to be successful and led to a loss of interest in the subject. Irani (2004) surveyed and interviewed students in an upper-level CS course at Stanford University. Upon entering the course, both males and females indicated the same level of enthusiasm and enjoyment of computers. The groups diverged when asked to self-report ratings of confidence in solving problems with computers. On a ten-point scale where a higher value indicates more confidence, males averaged a 8.4 confidence level while females averaged 7.7, which was not significant. However, a significant difference did emerge when confidence self-ratings were compared to their evaluation of peer confidence. Women rated themselves an average of a half-point less than their peers, while men rated themselves an average of six-tenths of a point higher. This finding suggests that women may have a tendency to underestimate their ability and that men tend to overestimate.

Yet another reason cited for female non-presence in computing fields is the perception that computing as an academic pursuit would be a boring endeavor. Anderson, Lankshear, Timms, and Courtney (2008) collected survey and interview data from 1,453 female high school students who were in the 11^{th} or 12^{th} grade and from 26 different high schools. Two primary reasons for not taking computer-science courses in high school emerged: 1) a high-degree of non-interest in computers, and 2) a perception of computer classes as *boring*. Interestingly, there was no support from this population for some of the other major reasons for female underrepresentation in high school computing classes, such as lack of encouragement from significant others, peer pressure, or belief that computing is a masculine field. Gal-Ezer, Shahak, and Zur (2009) arrived

at a similar finding when investigating why the total number of high school students taking computer-science courses is dwindling. Data obtained from 229 high school students from two different high schools revealed that the number one reason for avoiding computer-science courses in high school was the *boring* image that CS has. This reason was true for females as well as males. Yardi and Bruckman (2007) observed and interviewed 53 teenagers in Atlanta-area high schools and after-school technology programs to get their perceptions of computer science as an academic field and a career path. This female majority group was actively and enthusiastically involved in using computing technology and associated applications such as video editing, website creation, blogging and social media. Although this group was heavily engaged in computing usage, they indicated a strong aversion to studying computer science, believing it would be boring. Biggers, Brauer and Yilmaz (2008) present evidence that the "boring image" of computer science might be a contributing factor for high female dropout after enrolling in the major. In a retention study at Georgia Tech, a sample of females who left the computer-science major were asked for reasons why. Over 50% of the females sampled indicated the uninteresting nature of computer-science classes was a main reason.

The notion of relevance plays an important role in influencing females' choices to enroll or not to enroll in computer-science classes. Goode, Estrella, and Margolis (2006) examined why African-American, Latino, and female students rarely desire to study computer science in high school. The three-year, qualitative study uncovered four major reasons why high-school females choose or do not choose to pursue computer science. One of the reasons cited is an uncertainty of what computer science is and therefore, an

inability to ascertain if it is has any relevance to academic and career goals. Carlson (2006) quotes noted researcher Jane Margolis:

> In high-school and college courses, computer science is presented as straight programming, which is seen as tedious, especially by women. Men are generally interested in computers as tools and objects of study; women are more interested in what computers can do for science, the arts, or society.

Atlanta-area high-school students (a majority being female) were interviewed about their feelings toward computer science as a career, and most saw the stereotypical CS profession as meaningless and lacking purpose. Computer-science graduate students at Georgia Tech tend to agree that the failure to see real-world relevance in this discipline deters teenagers from furthering their experience in the computing sciences (Yardi and Bruckman, 2007).

Carnegie-Mellon University has had success in improving female enrollment, and one of the possible reasons cited has been the school's effort to provide a more meaningful learning experience in computer-science courses by adopting a contextual approach to the CS curriculum. The contextual approach (i.e. - providing purpose behind the learning) was implemented following a study recommending strategies for increasing female enrollment. This approach suggests that for women, providing a context for a course is just as important as making a course academically rigorous and challenging (DeClue, 2009).

Another possibility for the lack of females in college computer-science programs is the perception that computing is a masculine domain, thereby making it an unwelcome environment for women. Tillberg and Cohoon (2005) interviewed 182 undergraduate

computer-science majors, and several women believed that society has shaped computer science toward one gender. One female remarked, "Someone told me that I couldn't do it (CS) because that wasn't the way a girl thinks." Varma (2010) concludes that women are more likely to mention that gendered socialization is a major reason why a low number of females enter computer-science study. She contends that the role socialization plays in developing a gendered participation in computing cannot be under-emphasized in positing a reason for the large gender gap present. In interviews with both male and female undergraduate CS and CE (computer engineering) majors, the notion of technology and computer science as being suited for men more than women was prevalent. One male said, "I do not think women and technical stuff go together." Two quotes from females in particular highlight the masculine stereotype associated with CS: "It is in the air, it is everywhere that women should not get into engineering, science, or mathematics" and "There is a stereotype that girls are not meant to be in computer science."

Margolis and Fisher (2002) suggest that the socialization of computing might begin as early as kindergarten, when children become gender aware and cognizant of an activity being either a "boy thing" or a "girl thing." The toys they choose must be appropriate for their gender in order to attract friends to play with them. Once the computer entered the scene for young children, it became one of the most desired play objects for boys, but why is this so? Margolis and Fisher found boys like to construct and "tinker" with *objects*. They will build, destroy and re-build objects continually to understand "what makes them tick." They want to have control over things and make them do as they are commanded. The emphasis here is over boys' desire to interact with

objects. Girls, on the other hand, exhibit behaviors that display their preference for relationships with people over things. Girls in kindergarten will most often go to the doll corner or art table and focus on creating domestic scenes that include their parents, siblings or peers. Girls show that relationships mean more to them, while inanimate objects captivate boys.

Cheryan, Plaut, Davies, and Steele (2009) observed that the domain of computer science and in particular, the objects associated with computer science (e.g., Star Trek posters, video games) exhibit a masculinity that precludes women from developing an interest in the field. Although this type of masculinity differs from a traditional view that portrays characteristics such as strength, assertiveness, and sexual prowess, it is still perceived as indicative of a male. In their study, when an environment was constructed with objects stereotypically associated with computer science, females were consistently less interested in joining the domain than men. This suggests that the stereotypical, masculine environment in computer science may portray a setting that is incompatible with a woman's sense of being female. Psychologists use the term *ambient belonging* to describe one's feeling of comfortableness in an environment. People are disinclined to join domains where they feel out of place; therefore, females may experience a negative ambient belonging to computer science due to a feeling that they just do not fit.

In summation, females tend to perceive the computing field and specifically, computer science, as boring, antisocial and predominately male. These perceptions, along with poor pre-college academic preparation, a general unawareness of the relevancy of the discipline, and a lack of encouragement to pursue computer science combine to give a clearer understanding for the lack of female presence. However, some

females do choose to pursue computing study. Following is a discussion of the primary factors which can help direct females toward computing.

What Leads a Female to Computing?

As discussed previously, the pathway leading to computing study in college is traveled by an increasingly lower percentage of females. Some, however, do choose to major in a computer-related field, and the literature provides several reasons that can help explain why these women are motivated and persuaded to engage this academic discipline. These females frequently mentioned that they: 1) received encouragement to enter the field, 2) possessed an ability to see purpose behind computing, 3) held a belief that a computer-science degree would bring excellent career options, 4) had role models who inspired them, 5) viewed programming as enjoyable, 6) acquired a love for computers and technology, 7) were provided applications of logic and math, 8) were afforded the ability to be creative, 9) experienced parental influence, 10) desired to challenge the perception that computing is a male domain, 11) had positive attitudes toward those people in the field, and 12) had experience with a wide range of different computer applications.

Three studies provide evidence that receiving encouragement from others to pursue computing is a strong motivating force in the lives of many women. Tillberg and Cohoon (2005) interviewed 182 undergraduate computer-science majors from 16 universities spread across the United States and found that encouragement, especially from high school teachers, can influence women to study computer science in college. An interesting case of a high-school female computer-science student was presented. She

happened to be the only woman in the class, which was not uncommon. Her teacher saw in her the ability to do well in the computing field and encouraged her to pursue computer science as a major. The young lady initially disagreed with the teacher's belief that she could succeed in computing study at the college level. However, after much reflection, this high-school student reconsidered and enrolled in a computer-science major. She feels that the encouragement helped her to overcome her own insecurities and underestimation of her ability and, therefore, allowed her to believe that she possessed the skill and ability to do well. Kahle and Schmidt (2004), after analyzing questionnaire data gathered from women in various stages of their computer careers, observed that most women do not receive encouragement to enroll in a computer-science major, but those who do report a better attitude toward computer science, and an increased motivation to persevere in the major. Teague (2002) asked fifteen professional women involved in some aspect of computing why they chose to enter a non-traditional field for women. A primary reason found was the support and encouragement they personally received to enter the field.

For many women, computer science is more attractive and meaningful if it serves a useful purpose in society. In discussions with undergraduate computer students, Margolis and Fisher (2002) discovered that the motivation to study computer science varied by gender. The technical aspects of the field were a primary motivator for men. For many women, the technical aspects of CS were important, but the attraction toward computer science went far beyond the technical. Connecting computing with a meaningful purpose, such as enhancing medical research or improving education, was a more significant reason for choosing computer science for women as compared to men.

44% of women linked their interest in computer science to another discipline, while only 9% of men found a connection between computer science and another arena. These statistics appear to indicate that computing was a means to fulfilling a more lofty purpose for females; it appeared that computing alone *was* the ultimate purpose for men. A female student's recollection of comments made by male students after hearing a lecture on how computers may not benefit society captures the predominant male mindset found in this study:

> Everyone just said how boring (the lecture) was: "Who cares that computers did not benefit anyone? We like computers! We love computers! And who cares about the rest of the world.

Two other studies support the belief that for women to be led to computer science, they must see a higher purpose behind the field other than just computing alone. Carter (2006) asked more than eight-hundred high-school students what would motivate them to study computer science in college. For women, the major motivator was to gain an understanding how computer science might be used in another field. Teague (2002) found that a significant factor in helping high-school or college females decide whether or not computing will ultimately lead to a career that will best suit them was an ability to see the practical application of computing to everyday life.

Another major factor that might compel a female towards computing study is an awareness of the vast career options available for those trained and educated in the field. Yashuara (2005) conducted a survey of 205 first and second-year computer-science students and learned that a primary reason they were interested in computer science was a prevailing belief that a CS major had career advantages over other majors in terms of job availability and income potential. Papagastergiou (2008) found that high-school females

are less likely to pursue a course of study in computer science, but if they do, it is primarily due to extrinsic reasons such as excellent job prospects accompanied by attractive salaries. Interestingly, this reason was not significant for males, who indicated that the decision to enroll in computer science was mainly for the satisfaction and enjoyment it brings to them personally. Teague (2002) and Tillberg and Cohoon (2005) add that women who choose computer science believe that not only will career options be abundant in the future, but that these careers will be challenging and satisfying, with plenty of human interaction and teamwork.

There is some evidence that role models might encourage females to study and persist in computer science. A role model is a person who serves as an example of the values, attitudes, and behaviors associated with a role. Seeing someone socially similar to oneself (e.g., same gender, race, or socioeconomic class) raises the probability that a student could see him or herself in that same kind of role (Cohoon & Aspray, 2006). Black, Curzon, Myketiak, and McOwan (2011) distributed a 60-page booklet to secondary schools in the United Kingdom that contained core computing concepts, along with inspiring stories of women in computing who could serve as role models. Feedback from the majority of teachers was overwhelmingly positive, and comments received back from the teachers showed a strong belief that the booklet will help recruit and retain female students in computing. The study is ongoing with more analysis needed, but the preliminary results show promise that role modeling might be effective in attracting women to computer science. A majority of female computer-science students, in a 2009 survey, believed that female role models were important in their pursuit of a computer-science degree because they offer proof that women can do as well as men in computer

science. The survey participants also believed that if women, in their pre-college years, were made aware of successful women in computing, that knowledge might positively influence a women's decision to major in computer science (Beaubouef & Zhang, 2011). Cohoon and Aspray (2006) indicate that evidence exists in other academic fields that role models may not significantly influence a student's decision to enroll in a field, but they note that persistence in the field can be affected by role models, specifically teacher and student role models. Kahle and Schmidt (2004) lend support to the belief that role modeling helps women to maintain a strong interest in the field, resulting in increased endurance.

Computer programming is a fundamental skill necessary to excel in computer science, and possessing a love for it is another major reason why women are led to the field. Margolis and Fisher (2002) found that one-third (33%) of the women in their study indicated that a high-school programming class was the deciding factor in their decision to major in CS. In contrast, only 9% of males said that a programming class influenced their decision. For men, it seemed that their attraction to computing happened much earlier than high school, and it usually occurred at home or with friends. The women who found considerable enjoyment and satisfaction with programming tended to view it like a large puzzle to figure out, which was an experience unlike they had had in any other field before. Programming presented another avenue to perform problem solving and to observe if they had the skill to program a workable solution. The women reported that actually seeing a programming solution work gave them a wonderful sense of enjoyment and satisfaction. Tillberg and Cohoon (2005) agree that a major reason for loving computer science for both male and female students is programming. One woman

described programming as like a drug – it provides an incredible rush, thrill, and sense of power when you get a computer to do something that you know most people could not do. Yashuara (2005) reports the most interesting aspect about computer science according to students, both male and female, is programming. For women especially, the creative aspect of programming was what made it interesting, while men tended not to cite programming as a creative opportunity.

In general, a love for computers and technology has been found to lead some women to study computer science, but the evidence is conflicting. For men and women in undergraduate computer science, the pure enjoyment received from working with computers and technology was a motivator for pursuing CS (Yasuhara, 2005). Margolis and Fisher (2002) agree that the satisfaction received from being around computers and technology is one of many reasons that might direct women toward computer science. Men, on the other hand, pursue CS for pure enjoyment, and other factors outside this appear to be non-significant. In a study of 358 high-school students, Papastergiou (2008) offers supporting evidence that young men would pursue computer-science study in college primarily because of the perceived enjoyment it would bring. However, a belief that CS would bring enjoyment was not a primary reason young women would study CS, which contradicts findings from the previous studies mentioned.

Inherent in the discipline of computer science are the aspects of logic and mathematics, which attracts some women. Tillberg and Cohoon (2005) discovered that both men and women alike enjoy the mathematics and logic component of computer science, and, interestingly, women mentioned this aspect more frequently than men. Similarly, Yasuhara (2005) found that women in introductory computer-science classes

liked the logic and math component at a significantly higher level than men, and it was a reason why some women would be likely to continue in a computer-science major. However, Sax (2012) suggests that math may not be a strong motivator to enter computing for both men and women in the future because of the rise in technologies and applications that render math ability less critical in achieving success in the discipline.

Many women see opportunities for creativity in computer science, which can heighten interest in the field. Computer applications that provide a means to creatively solve problems, particularly those related to pressing human problems, can be particularly effective in attracting female interest in the field (Creamer, Lee, & Meszaros, 2006). Margolis and Fisher (2002) found that computer programming, from a female perspective, allows for much creativity, which enhances sense of satisfaction. Women see CS as a field where they can be creative, which is significantly different from the majority of men, who tend not to recognize the creative aspect of computer science (Yasuhara, 2005).

The popular pastime of gaming also displays the creative side to computing. Tillberg and Cohoon (2005) observed that for young men, gaming is a prime motivator for studying computer science. They grow up playing games on the computer, and for some, they want to learn how to build games that can extend and enhance a favorite pastime. Computer science is therefore perceived as the key to being able to develop games and perhaps a lead-in to a career in the gaming industry. Young women are also attracted to computer science by their experiences of "playing on the computer," but in an entirely different manner than young men. Female-play on a computer usually involves a *creative* aspect, such as playing with an animation or paint program, or pretending to be a

reporter and typing an intriguing story. Creatively playing with a computer provides an attraction toward computers for young men and women, but the concept of playing with a computer apparently has different meanings.

Ferry, Fouad, and Smith (2000) found that parental encouragement in math and science significantly influenced their children's self-efficacy beliefs and outcome expectations, which affected the choice of choosing a math or science major in college. Is this parental effect also influential in guiding children toward computer science? Margolis and Fisher (2002) indicate that home environments are important for students developing an interest in computer science. Parents can demonstrate to their children an enthusiasm for computers, which might spark an interest in wanting to know more about the subject. This interest can lead children to obtain mastery in several computer skills, which can allow them to gain confidence and competence they can carry with them into school. Tillberg and Cohoon (2005) note that family members, specifically parents, significantly influence a child's career choice decision. Three women in their study specifically mentioned a mother or father as being the primary reason they chose to pursue CS. In two cases, the mother was the major motivational force due to her ongoing career in the computing profession; one mother was a computer analyst, and the other worked on computers for the government. In the third case, the father taught his daughter how to program using the BASIC programming language. Creamer et al. (2006), in a study that included high schools, community colleges and four-year universities, found that parental support had a direct and positive impact on women's interest and choice of a career in the computing field. In this study, one of the most significant differences was

found on this variable. By contrast, parental support was not found to be directly related to men's interest in a computing career.

The last three reasons given for female attraction to computer science do not appear as frequently in the literature, yet these reasons were conclusions from scientific study. Tillberg and Cohoon (2005) found that some females were attracted to computer science because they felt the need to challenge societal views on gender-appropriate roles. One woman was told that she couldn't do computer science because "that was not the way girls think," and she was determined to prove her skeptic wrong. Another mentioned that people tend to look at you funny if you major in computer science because you are a female. The prevailing thought is that computer science is made for men and therefore male-dominated. This woman wanted to show that females can be just as successful in computer science as men.

Creamer et al. (2006) provide the other two reasons attempting to explain female attraction to computer science. Some women who like computing believe that those working in the computing field have such positive attributes as being interesting, hard-working, smart and creative. These same women disagree with the common stereotype of a computer professional as being a geek, probably a male, and antisocial. Thus, a positive attitude toward people involved in the computing fields caused some females to become interested in computer science. The second reason suggests that for women, an interest in computing is significantly related to *amount* of computer use, but not *type* of computer use. It is likely that experience with a broad array of applications (the more sophisticated the better) creates confidence in one's ability to learn the in-depth aspects of computing that computer science can impart.

Female Attrition in Computing

Gaining the knowledge that might encourage more female engagement with computing study can be helpful in promoting more interest in the pre-college population and hopefully lead to improved female enrollment. Once females are enrolled, however, another significant problem contributing to low female graduation percentages arises — attrition. Studies suggest that females quit computer science programs at a higher rate than males. Singh et al. (2007) examined 44 empirical studies that focused on women's enrollment and persistence in computer-related majors, and found that women have comparatively higher attrition rates than men. They conclude, obviously, that stemming the outflow of women from computing fields by enhancing their interest is critical to increasing the number of women in computer science and information technology fields. Cohoon (2001) provides evidence that attrition rates for females, as compared to males, are alarmingly high when compared to a similar academic discipline. This study investigated possible causes for women leaving an undergraduate computer-science program at higher rates than men. A comparison between the gendered attrition rate (GAR) of Computer Science to Biology/Life Science was made because the two fields share similar characteristics and requirements. Disturbingly, the data showed that the GAR of computer science was -9% (i.e. – women dropped out at a 9% higher rate than men) and Biology/Life Science had a GAR of -1%. Likewise, Barker and Garvin-Doxas (2004) found that women CS majors drop out of computer science at a higher rate than men.

Frieze (2007) acknowledges that women do experience a comparatively high attrition rate compared to men but argues that attrition rates between men and women

would be the same if a gender-balanced environment existed. In her study of women's participation in computer science, Frieze mentions that since Carnegie-Mellon University has achieved more gender-balance in computer science, attrition rates between men and women are now similar. Cohoon and Aspray (2006) offer support for the argument that gender-balance helps retain more women by reporting a finding that same-sex peer support has the strongest relationship with gendered attrition rates. Departments with higher female proportions of enrollment were more likely to retain women at comparable rates with men. Knowing and relating to other students, especially those of the same sex, increases chances for a successful outcome in a class. Margolis and Fisher (2002) discovered that females became disheartened with computer science simply because they were in the minority group. Because they were few in number, females felt there was a feeling that they could not do the job, and this feeling became more pronounced when incidental and random comments from males made them feel undervalued and unwelcome. As one female commented, "If you are constantly told you're hopeless — eventually you start believing it."

In addition to gender inequity being a primary reason for high female attrition, other reasons have been found to lead to dropout and will be discussed in more detail. These are: 1) women are less-accepting of lower grades than men, 2) the computer-science classroom environment makes women less comfortable, 3) students experience extreme difficulty in beginning programming courses, 4) computing is competitive, 5) faculty attitudes and behaviors can cause discouragement, 6) interest wanes once enrolled, 7) self-confidence drops once enrolled, and 8) the male computer-science stereotype leads to loss of interest.

Katz, Allbritton, Aronis, Wilson, and Soffa (2006) observed that women are less-accepting of lower grades than men, an attitude that affects their persistence in the major. If a female made less than a B in her first computer science course, she was more likely to drop out of the major than a male who made less than a B. This finding suggests that for women, low academic achievement (i.e. – a grade lower than a B) can negatively influence their desire to remain in computer science.

The computer-science classroom environment may be another reason for females leaving a computing major. Barker and Garvin-Doxas (2004) observed the climate of computer-science classrooms, and two primary characteristics became evident which caused them to label the climate as defensive: 1) class work is performed alone with no chance to collaborate or develop relationships, and 2) classes are impersonal, making it easy to remain anonymous and socially distant. An ethnographic study comparing computer-science classroom environments to IT environments offers additional support for classroom environment being a possible culprit for high female attrition in computer science. Over a span of two years, a wide array of computer-science courses at a large university (24,000 undergraduates and 700 computer-science majors) were observed and found to exhibit four major classroom characteristics: 1) the teacher was the expert and students were novices, 2) any form of talking or working with another student might be construed as cheating, 3) the subject matter was not connected to human experience, and 4) there was infrequent knowledge-sharing among students. In contrast, IT courses were observed over the same span and displayed classroom traits opposite to those in computer science: 1) the teacher was free to learn from students, 2) collaboration with other students was encouraged, 3) students were presented with the purpose and relevancy of

assignments, and 4) knowledge-sharing among students was common-place. In comparing female retention within the two majors, female retention was higher in IT than in computer science, suggesting that computer-science classrooms should emulate an IT classroom to lessen female dropout (Barker, Garvin-Doxas, and Sieber, 2005).

Ali (2009) adds two further reasons why women may have a more difficult time remaining in a computer major than men: 1) a female's first experience in computing is usually a programming course, which is a difficult task, and 2) computing is viewed as competitive rather than purposeful. It is agreed among most educators of computing that learning to program is difficult for students. Likewise, teaching introductory programming is a complicated task. The major reasons for the complexity in both the learning and teaching process is: a) rigid programming language syntax, b) programming structures that are confusing, c) difficulty in developing structured solutions to problems, and d) challenges in understanding how a program is executed (Carter & Jenkins, 2002; Kelleher & Pausch, 2005; Lahtinen, Ala-Mutka, & Jarvinen, 2005). In addition, assignments in beginning programming courses are usually completed alone with no opportunity to collaborate with others to gain a better understanding of difficult concepts. Also, in general, problems assigned provide no inherent motivation for the student because problems typically do not have any relevancy to the real-world. These pedagogical methods reinforce a common perception that a career in computing, specifically programming, will be done in isolation, where a computer professional will sit in front of a computer for long hours on problems that are neither interesting nor helpful to mankind. This view may lead many students, especially females, to avoid computer science or to leave once enrolled (Teague & Roe, 2008).

Vilner and Zur (2006) offer support for beginning programming courses being a factor for higher female attrition. They investigated why the female attrition rate (36%) was higher than men's (23.5%) at their institution. They concluded that men had higher success rates (43% to 30%) in initial courses and that beginning programming courses caused significant discouragement to females. Interestingly, the study found that if females can get past the first programming course, they succeed as well as men in future programming courses.

In regard to the issue of computing being viewed as competitive rather than purposeful, Dann, Copper, and Pausch (as cited in Ali, 2009) assert that individualism in the classroom (work performed alone) can create a competitive atmosphere among students. In western culture, a competitive environment has been historically and stereotypically described as masculine. Compared with men, women typically experience heightened anxiety in competitive situations, including those involving intellectual achievement, such as what occurs in a classroom. This competitive aspect can lead women to avoid such competition or to perform poorly (Schunk, 2008, p. 469).

Issues with computer-science faculty have been found to be a further contributing reason for women leaving computer science. Cohoon (2001) mentions three separate issues with faculty that showed a significant correlation to a high female gendered attrition rate. The first issue pertained to faculty attitudes toward female students' skill and work ethic. Departments whose consensus attitude displayed indifference toward female students' skills and work ethic, or communicated that females were slightly disadvantaged in skill and work as compared to males, lost women at disproportionately higher rates than men. The second faculty issue addressed faculty beliefs in student

attainment of success and the degree to which they enjoyed teaching undergraduate students. Departments who had faculty who did not receive much personal satisfaction from teaching undergraduates and believed that innate student ability was responsible for student success had high female dropout. In contrast, departmental faculty who enjoy teaching undergraduates and believe that student success is part of their responsibility had low gendered attrition rates. The third issue purports that the lack of female faculty causes women to vacate computer science at higher rates than men. Correlations showed that female faculty will help to retain women students at equivalent rates with men. Margolis and Fisher (2002) stress that problems with faculty and curriculum hurt all students, but women and minorities are affected more. In examining a large Data Structures course, women's academic performance was found to be significantly lower than men's. The grade average for women was 2.71, while the average for men was 3.21. Although there was an abundance of help being provided by teaching assistants in this course, interviews with women revealed that they needed more contact with the professor, who could give them the needed encouragement and support they desired. Without faculty support, women in this class reported feelings of "being lost" and "drowning." Men, on the other hand, responded that the class was "easy" and "boring."

Two studies discovered that women, in contrast to men, are much more likely to lose their love for computing once enrolled in an undergraduate computer-science program. A study of 66 computer-science students (35 females and 31 males) across four U.S. colleges found that after enrolling in a computer-science program, women's love of computing and finding challenge and purpose in the discipline dropped at much higher rates than it did for males. At the time of enrollment, women were optimistic and

enthusiastic about the challenges ahead. However, once the reality of solving problems by spending hours in front of computer set in, the initial positive feelings toward computer science started to wane (Varma & LaFever, 2006). Initial interviews with women just beginning computer science were filled with excitement as the students anticipated the learning they were soon to begin. By the second or third semester, these same women, who once were filled with high hopes and expectations, displayed opposite emotions that made the interviewers feel like they were talking to different people. What was startling was that attitudes changed so quickly, and it was a phenomenon displayed by many women time and time again (Margolis & Fisher, 2002).

The rapid loss of interest in computing once women begin coursework may be connected with a corresponding loss of self-confidence. In fields closely connected to computer science, similar problems occur. Brainard and Carlin (1997) performed a longitudinal study of women pursuing degrees in science and engineering and concluded that confidence in ability drops significantly in the first year of the degree program. The results from the study also indicated that most drop-outs occur in the first or second year of the program. For the students who do persist with the program, confidence levels rise but never return to their original levels. Why women apparently lose confidence in their ability to perform at a high level might possibly be connected to their perceptions of how they are doing in relation to their peers. Margolis and Fisher (2002) observed that for many women, enthusiasm and confidence plummets in the first or second year of the program. Interviews with women discovered that in most cases, a perception prevailed that their peers (mostly male) were doing better and with less effort, and that view became a major contributor to a rapid decline in self-confidence. This extreme loss of

confidence led women to question if they truly "measured up" to the rigors of computer science.

Steele (1997) argues that stereotypes and low expectations for women in math and science play a major role in loss of interest that leads to dropout. The perception that women cannot do computer science work because it is a field made for men leads to a dilemma called stereotype vulnerability. Females simply do not want to play a part in confirming the perception; therefore, they detach themselves from the field. Margolis and Fisher (2002) believe this stereotype threat leads many women to conclude that computer science is not for them and thus leave the major.

This section has attempted to delve deeper into the causes for high female attrition from an undergraduate computer-science degree program. Researchers have also looked at the reasons why some females are able to persevere academically and attain a computer-science degree. The next section will offer a better understanding into why women choose to stay instead of leave. Such a focus, of course, is central to this study.

Persisting in Computing

The decision to quit or remain in a computer-science program is a constant back and forth war going on in the minds of many women. At times, leaving the major seems to be the best action to take, while at other times, it appears that staying is the best option (Margolis & Fisher, 2002). The previous section highlighted the difficulty women have in remaining in computer science, but fortunately some women do persevere and finish with a degree. The following section will present findings that will offer some insight into why some women do persist in computer science.

In a study of students in an introductory programming class, Barker, McDowell, and Kalahar (2009) attempted to identify environmental and student factors that best predicted a student's intention to persist in the computer-science major beyond introductory courses. They found that the most powerful predictor was *student-student interactions*. Those students who were able to establish relationships with peers within the major were more likely to continue in the major than those who were unsuccessful in forming such relationships. The student-student interaction index focused on both inside and outside classroom activities. An example of an inside classroom activity was doing homework with a peer, while an outside activity would be watching television with a peer from the class. Feeling that they are a part of both the academic and social community of their major can help students to believe they "fit-in," which is especially crucial for underrepresented groups. One practice cited in the study that helped foster student-student interaction and thus the building of relationships was collaborative opportunities to learn, such as being able to work with others on graded assignments.

Besana and Detorri (2004) created a community of learners among the females in the introductory sequence of computing courses to discover if this action would help retain more women in the School of Computer Science, Telecommunications and Information Technology at DePaul University. The group did several activities together over the course of the semester, but the main activity was a weekly meeting with two upper-level female students who served as mentors and tutors. Also at the meetings, groups were formed to work on class assignments together and discuss personal issues. Qualitative data obtained from the study indicated that women at DePaul enter computer science with low self-confidence that leads to feelings of isolation and intimidation in the

classroom. At the end of the community of learners project, approximately two-thirds of those who participated felt the initiative increased their self-confidence, suggesting that self-confidence levels can be improved through bonding with others in the major, resulting in an increased likelihood of staying in the major.

Pair programming is another pedagogical technique that creates student-student interaction by having two students collaboratively complete a programming assignment. McDowell,Werner, Bullock, and Fernald (2006) found that beginning students who used pair programming were significantly more likely to stay in an introductory programming course through the final exam than those who programmed independently. For women who utilized pair programming, the results are especially encouraging, as the following percentages indicate (PP – women who used pair programming, NPP – women who programmed independently, non-pair-programmer):

- The percentage of women who went on to the next course in Data Structures: (73.8% PP vs. 55.6% NPP)
- The percentage of women who passed the next class in Data Structures where they had to program alone: (64.6% PP vs. 37.5% NPP)
- Those who were more likely to be a CS major after a year: (59.5% PP vs. 22.2% NPP)
- Those who reported more confidence in their solutions: (86.8% PP vs. 63% NPP)

These results offer compelling evidence that the student-student interaction technique of pair programming can help retain students, especially women.

An earlier study in fields related to computer science — specifically science, mathematics and engineering (S.M.E.) — found that student participation in mutual help groups was a strong and valuable aid to persistence. Students indicated the importance of having a personal connection with someone else in the major field because of the realization that attempting to complete a S.M.E. major alone would be extremely difficult. The data also indicated that working in small groups to do problem-solving and complete homework was beneficial to women in particular. The culture and nature of S.M.E. majors promote competitive behaviors where everyone tries to outperform each other, which results in extreme individualistic effort. Women who went against this type of behavior and worked collaboratively instead of competitively believed that collaboration was helpful in persevering and preventing burnout (Seymour & Hewitt, 1997).

One additional student-student interaction factor deemed critical to females wishing to stay in CS was simply finding friends with whom social and academic aspects of life can be shared. Undergoing learning by oneself is difficult. Establishing friendships within the major can make learning more bearable and less daunting because one is not alone, and there are others sharing the same mutual experience (Katz et al., 2006; Margolis & Fisher, 2002).

As we have seen, an important factor contributing to a woman leaving or staying in computer science is her level of self-confidence. In interviews with female persisters in computer science at Carnegie-Mellon University, Margolis and Fisher (2002) concluded that women, in order to persevere in computer science, must possess a confident belief that they can and will do the work required in the major, and they must

be confident enough in themselves that they can accept being in a male-dominated culture without seeing the need to conform to the culture. In their study of female persistence in undergraduate science-related degrees, Seymour and Hewitt (1997) found that women who could let go of self-critical behavior (e.g. fears of being wrong or not measuring up academically) were more likely to remain than those who constantly monitored their progress against their mostly male peers. If these constantly self-evaluating females perceived their performance to be below their counterparts, discouragement and doubts would surface, leading to a higher probability of dropout. By contrast, females who were able to release feelings of perfectionism and the striving to outperform their peers indicated that this positive state-of-mind was learned though their family upbringing or was a self-taught trait acquired from life experience.

Cohoon, Wu, and Luo (2008) investigated 41 computer-science doctoral programs seeking factors that influence women's participation in computing as well as their confidence level. The study found that females who entered a doctoral program at the outset with a low self-confidence level were four times more likely to have considered dropping out by the end of the second year. By contrast, those who had a confident belief in their own computing talent were more likely to obtain a degree. Two major characteristics were discovered that correlated to highly self-confident females: 1) they were comfortable in class asking questions, and 2) they were comfortable in talking and seeking help from faculty. One major external factor mentioned frequently that helped to increase self-confidence was helpful and caring advice received from advisors and faculty. The advice provided the guidance these women could trust and was crucial in their ability to persevere.

Confidence is also tied to initial experiences. The experience of women within initial computer science courses, in particular beginning programming, plays a pivotal role in determining whether or not they will continue in the major. Dee et al. (2009) studied the attitudes of women who have persisted in computing at the undergraduate, graduate and professional levels through obtaining an answer to the question, *"Why are you still here?"* A common attitude shared among the participants was the tremendous joy they experienced in their first programming class. The terms most frequently used to describe their initial foray into software development were "interesting," "challenging," "rewarding," "exciting," and "fascinating." While the first programming language encountered by these women varied — with the predominant languages being Basic, C++, Java, Pascal, Fortran and Schema — the study concluded that the choice of language had no bearing on female attitudes toward computing. West and Ross (2002) also found that women who chose computer science as a major had a positive attitude toward their first programming experience and used terms such as "fun," "exciting," and "imaginative" to describe it.

Research findings are scarce on the importance of faculty in aiding the retention of female students in computer science, but in other sciences such as engineering, math, biology and the physical sciences, studies reveal a strong connection between faculty and student retention. Sonnert, Fox, and Adkins (2007) gathered information on student and faculty participation in science and engineering from 499 universities over a 16-year period to analyze the percentage of undergraduate degree recipients in biology, physical science and engineering. The study found that female bachelor degree recipients were correlated to the percentage of women faculty in the field, and the growth over time in

the percentage of women among science and engineering majors was higher in the presence of a larger percentage of women faculty. The results suggest that the presence of women faculty may have a positive impact on women in the sciences, especially in degrees received. Support is also offered for the belief that female faculty serve as important role-models for female students because the mere presence of females in the field may send a signal to these students that this field is an appropriate choice for them. Likewise, Seymour and Hewitt (1997) assert that the presence of female faculty is important to female students because it provides an example of one who is successful in the field. However, in regard to persistence in the major, students reported that the gender of the faculty member is not as critical as simply having their needs met. Persisters cultivate strong relationships among faculty to help them successfully continue a chosen academic pursuit. In many cases, it was one faculty member who made a critical difference in the decision of a female student to either stay or leave.

Some researchers argue that female persistence in computer science would be enhanced if there was more balanced numbers of males and females in the field. Seymour and Hewitt (1997) report that in science-related fields where gender balance is at or near par, female majors report the atmosphere to be more comfortable and problems fewer, and the result is higher retention and graduation rates. Frieze (2007) argues that the problem of low female participation and retention in computer science is not a consequence of gender-specific differences but rather a result of a non-equitable gender balance in the field resulting from a cultural mentality that computer science is more suited for men. If that mentality could be successfully challenged and proven incorrect, then more women might enter and stay in the field. Frieze's research was conducted at

Carnegie-Mellon University (CMU), which has achieved a more gender-balanced environment in computer science over the last decade by intentionally pursuing the ideal that computer science is a gender-neutral field through recruiting higher numbers of females into the program. As the percentages of females increased, retention and graduation of women rose. Interviews with both males and females revealed that many issues thought to be gender-specific (e.g. a "geek" culture) seemed to disappear when a balanced environment existed. This study suggests that men and women are much more alike in the ways they relate to computer science when the number of men and women are more balanced.

Analyzing the involvement of women in computer science outside the United States offers evidence that numbers do matter when considering females who persist in the discipline. A case in point is the country of Malaysia, where the number of women participating in computer science is equal to men. The computer-science field in Malaysia is not perceived as masculine because it is "indoor work." Therefore, computing work, specifically programming, is seen as good work for women. Because of the high number of females involved and the Malaysian perception of computing science as gender-neutral, participating and remaining in the field is easier (Lagesen, 2008).

Yet another reason suggested that affects a woman's persistence is her view of intelligence. Margolis and Fisher (2002) stress that persistence in a computer-science major by a female is related to her level of computing self-efficacy (i.e. the belief that she can do the work of a computer-science major), which is derived from her view of intelligence. After 30 years of research, Dweck (1999) concludes that people tend toward one of two mindsets toward intelligence; it is either fixed or mutable. A fixed view of

intelligence believes that intelligence is something that is innate and cannot be changed. Those who hold this view will focus on performance and are inclined to reject criticism and feel threatened when others succeed. On the other hand, a mutable or growth mindset toward intelligence believes that with persistence and hard work, one's intelligence can increase. Students with this type of mindset focus on learning and are more likely to relish challenging work, accept feedback as helpful, and find inspiration in the accomplishment of others because they see them as sources of additional knowledge. Murphy and Thomas (2008) suggest that within computer-science education, the fixed versus growth intelligence mindset influences both retention and diversity. If a student believes that computer-science ability is innate, then the choice to pursue and remain in computer science is due to having a certain gene. A fixed mindset will believe that in order to do well, one must possess this so-called "geek gene." Margolis and Fisher (2002) discovered that American women, much more than international women, fall victim to the computer gene theory, which assumes that a person is born with a gene that enables him or her to do well in computer science. Also, American women tend to choose personal happiness as a criterion for majoring in a certain field, and this happiness is gained when one does not have to struggle to learn. International students on the other hand tend to possess a growth mindset, evidenced by their belief that academic progress comes as a direct result of effort and hard work, which ultimately leads to successful achievement. Teague (2002) found that the aspect of problem-solving, so prevalent in the computer-science field, is a major reason why some women went into computing and stayed. Problem-solving challenges one's intellect, and only those who tend toward a

growth mindset are able to persevere and to witness the gains in intelligence that problem-solving brings.

The trait of emotional intelligence (EI) has been presented as another factor related to one's persistence in computing academia. In a study of 136 computer-science and related majors (85 male, 51 female) across 20 U.S. institutions, Lewis, Smith, Belanger, and Harrington (2008) investigated the connection between EI and persistence in the major. EI is defined as a combination of three types of adaptive ability: 1) the appraisal and expression of emotion, 2) the ability to regulate emotions, and 3) the utilization of emotions to solve problems. Findings from the study indicate that EI is a significant predictor in one's "intent to stay." Those individuals high in emotional intelligence are better able to control and channel their emotions, which can lessen discouragement and foster perseverance. Also in this study, the trait of computing resilience was studied to examine its effect on persistence. In general, resilience is defined as an individual's capacity to thrive and fulfill his or her potential despite challenging or threatening circumstances. It is the ability of a person to "bounce back" from adversity. The term *computing resilience* was developed specifically for this study and was defined as a student's ability to cope well with the daily challenges, strains, and stresses of a computer-science degree program. Findings showed that computing resilience had a direct effect on EI and an indirect effect on a student's intention to continue in the major. Additionally, Mayer, Salovey, and Caruso (2004) investigated the concept of emotional intelligence and discovered that as one's EI rises, so does academic achievement, which Katz et al. (2006) found to be related to a person's persistence in a computer-science program.

The previous discussion listing various reasons positively related to female persistence includes the reasons that appear to have the most research support. Other reasons have been suggested and will be listed here as this section concludes.

- Persistence is motivated by the potential of a good job in the future (Dee et al., 2009).
- Some students wish to continue so they can inspire and teach other women who desire to study computer science (Dee et al., 2009).
- Comments insinuating that females cannot achieve in the field of computer science served as a motivation to remain to prove people wrong (Dee et al., 2009).
- If a woman was used to being around men, either in a family, friendship or sports context, she was more comfortable in a mostly-male environment and less intimidated, making persistence easier (Seymour & Hewitt, 1997).
- A woman who accepted and adapted to the culture of computer science made persistence easier because they felt like they "fit in" (Margolis & Fisher, 2002).
- Being from a computing family helps provide emotional and intellectual stepping stones to pursue and finish a computer-science major (Margolis & Fisher, 2002).
- Persisters possess the fortitude and diligence to make it through the second year of the program, which seems to be the critical juncture where a female realizes that she can do the work required and has internalized this belief (Margolis & Fisher, 2002).

Can Motivation Orientation Explain Pursuit and Continuance in Computing?

Studies conducted by both Howles (2007) and Potter, Hellens, and Nielsen (2009) highlight the importance of motivation orientation in guiding an individual toward computing. This section will discuss from a psychological standpoint why intrinsic and extrinsic motivation might be an important aspect in understanding women's behavior toward and engagement in the computing field.

The phrase "to be motivated" means "to be moved" to do something. People will vary in the strength of their motivation and *orientation* of that motivation. Orientation is concerned with the reasons why people are moved to act, and according to self-determination theory, people are moved in one of two ways. A person can be moved to act because the action itself brings enjoyment and satisfaction. On the other hand, an individual acts because the action, while not necessarily gratifying nor fulfilling, is believed to lead to a separable, advantageous outcome. The former defines one who is *intrinsically* motivated, and the latter is *extrinsically* motivated (Ryan & Deci, 2000a).

Comparisons between individuals whose motivation is authentic (intrinsic) versus externally controlled (extrinsic) normally reveal that the former individuals exhibit more interest, excitement and confidence, and these traits are manifested in increased performance, persistence, and creativity. Intrinsic motivation therefore propels a human to higher levels of achievement and the ability to withstand and persevere in difficult environments. The conditions that promote intrinsic motivation are a key area of motivational research because the intrinsically motivated demonstrate the positive and persistent aspects of human nature (Ryan & Deci, 2000b).

Human beings possess three innate psychological needs: 1) competence, 2) autonomy, and 3) relatedness. Competence refers to the belief that one possesses the required skill, knowledge, qualification, and capacity to perform. Autonomy is concerned with the amount of freedom or self-governance one has in a given situation. Relatedness is the need for one to feel connected to others and to feel that he or she belongs. When these three needs are met, the result is enhanced self-motivation, effort, commitment, and mental health; when these needs are thwarted, a person suffers from a decrease in motivation and well-being. Research strongly suggests that intrinsic motivation arises in environments that promote competence, autonomy, and relatedness (Ryan & Deci, 2000b). This research would propose that the majority of women who are attracted to and persevere in computer science are intrinsically motivated to do so. It is the personal satisfaction, enjoyment, and challenge of computer science itself that motivates a woman to become interested in the field and to continue in it.

Although viewed as a pale and lesser type of motivation, extrinsic motivation can nevertheless encourage the development of intrinsically motivated behavior. Acting due to extrinsic purpose can cause some students to exhibit resentment, resistance and disinterest, while other students may display an attitude of willingness that reflects the inner acceptance of the task worthiness. The degree to which the extrinsic motivation positively impacts the three basic needs of competence, autonomy and relatedness will greatly determine whether intrinsic behavior can be developed via extrinsic activity (Ryan & Deci, 2000a; Ryan & Deci, 2000b). Therefore, extrinsic motivation can encourage women to pursue computer science, but unless the extrinsic motivators can be

internalized and perceived as worthwhile, it appears that continuance in the field is questionable.

Motivation is a central issue in the field of psychology and lies at the core of understanding human behavior. It is highly valued research because the consequences produced by motivational action demonstrate a human spirit that is either full of vitality and potential, or apathetic and indifferent. Therefore, it is a critical issue for those wishing to comprehend why others act the way they do and in turn, to mobilize them to act in a manner that highlights the positive aspects of human nature (Ryan & Deci, 2000b).

Utilizing a Different Approach to Study the Problem

Despite the numerous investigations of female underrepresentation in computing academia and the resulting intervention efforts that have been implemented due to the research, the percentage of female graduates continue to decline. Frieze and Quesenberry (2013), in addressing the unsuccessful attempts to increase female representation, state the following: "Yet, sadly, years of attention and funding applied to women in computing issues have not paid off." Cohoon and Aspray (2006) readily admit that 25 years of research and interventions have simply not worked to reverse downward trends in enrollment, retention, and graduation rates. Therefore, they believe that different approaches in the investigation of this highly complex phenomenon are needed.

Studies focusing on the negative aspects to the problem, such as factors leading females away from computing, are abundant in the literature. On the other hand, research efforts that examine the positive aspects, such as reasons that attract women to

computing, are not as prevalent. Investigating successful life stories is a constructive and optimistic approach to a problem found in previous dissertation works. Examples of two such dissertations utilize this technique. Kolacz-Belanger (2008), in an attempt to encourage female persistence in the male-dominated computing industry, examined the lives of successful women computing professionals in order to identify factors that helped them to endure in the industry despite being in the minority. Simon (2005) researched female achievement in IT by investigating 20 female IT executives to uncover common traits that led to individual success in the industry. This study will similarly attempt to accentuate the positive by uncovering the common aspects of different female computing graduates that directed them successfully to the academic finish line — a computing degree.

Conclusion

The literature review clearly shows the reality and significance of the female underrepresentation problem in computing and the importance of attracting, retaining, and graduating more females in this discipline. Reasons for avoidance of and attraction to computing, high female attrition as compared to men, and key reasons that suggest how some females are able to persist were discussed, providing a basis of knowledge to begin the study. The review also showed that understanding motivation orientation might be helpful in understanding female engagement with and persistence in computer-related majors. Finally, researching a problem using a constructive and optimistic approach, such as investigating women who have been successful in the study of computing, could lead to a better understanding of how a female eventually graduates with a degree in the field.

Chapter Three
Methodology

Overview of Research Methodology

The dissertation study utilized a mixed methods approach to investigate factors that might lead a female to pursue an undergraduate computing degree and enable her to persist in the program until degree-attainment. The strategy of inquiry used involved collecting data sequentially to better understand this process. The data collection resulted in gathering both numeric (quantitative) and textual (qualitative) information (Creswell, 2003, p. 15 -16). The process of combining both quantitative and qualitative methods in a single study permits a researcher to allow one of the methods to confirm findings from the other method. The ability to confirm findings is a primary reason why researchers choose to conduct a mixed method study (Creswell, 2003, p. 210). Furthermore, Creswell and Clark (2007, p. 5) strongly assert that the combined use of quantitative and qualitative methods provides a better understanding of a problem than either method alone. Terrell (2012) agrees and states that many social-scientists believe that a mixed method research methodology is better than either an exclusive quantitative or qualitative approach because the mixed method approach can tell a researcher both "If" (quantitative outcome) and "How or Why" (qualitative outcome).

The specific mixed method design used was a two-phase sequential explanatory strategy, commonly referred to as a QUAN -> qual study, and is characterized by the collection and analysis of quantitative data in the first phase followed by collection and analysis of qualitative data in the second phase. The priority in the study is typically given to the quantitative data, and the qualitative data is used to explain and interpret the quantitative data more clearly. This design helped explain surprising and interesting results from the study in more detail (Creswell, 2003, p. 215; Creswell & Clark, 2007, p. 71). The sequential explanatory design starts with collection and analysis of quantitative data followed by a qualitative phase designed to connect to the first quantitative phase. In other words, the quantitative findings determine the type of data collected in the qualitative phase, which will then be analyzed and interpreted. The researcher can then elaborate on the quantitative findings through the qualitative analysis and interpretation (Gay, Mills, & Airasian, 2009, p. 463).

The sequential explanatory design was beneficial to a single-researcher study because the two methods were conducted in separate phases and collected only one type of data in each phase (note that a minimal amount of qualitative data was collected during the quantitative phase), which meant a research team was not needed to carry out the design (Creswell & Clark, 2007, p. 74). Another advantage of this method included the straightforwardness of the design due to clear, distinct stages (Terrell, 2012). The qualitative phase needed only a few participants to explain portions of the quantitative results (Creswell & Clark, 2007, p. 74; Terrell, 2012). However, this design was time consuming because of the two distinct phases.

Mixed method studies are becoming more prominent and accepted as an effective and productive means to conduct research. Specifically, sequential explanatory studies provide a better understanding of a problem by exploring participants' views in more depth once quantitative data has been acquired and analyzed (Carr, 2008; Thota, 2011).

Specific Research Methods Employed

The study collected data in two separate phases. The first phase used a survey to gather quantitative data and a minimal amount of qualitative data, and the second used interviews to acquire qualitative data. These specific methods, survey and interview, are discussed in further detail in the next sections. A visual diagram of how these specific research methods were integrated within the framework of a sequential explanatory study is provided in Appendix A.

Phase I: Survey Method – Quantitative Data Collection

The overall purpose of a survey design is collecting numeric data from a sample of a population to make inferences or generalizations about that population in regard to certain characteristics, attitudes, behaviors, beliefs or opinions (Creswell, 2003, p. 153-154). The survey in this study was administered online because of the advantages this type of survey affords. The advantages of an online survey as a data collection tool included cost effective survey delivery to recipients, instantaneous data collection, and user convenience in participating. However, there were some disadvantages. A major disadvantage in using an online survey in this study was the time involved to become proficient with the survey-creation software.

The population for this dissertation study was females, who were educated in the United States, and who had obtained an undergraduate degree in a computing major; therefore, the survey, found in Appendix B, was entitled the *"Female Computing Graduate Survey."* The plan utilized to locate a population sample is provided in more detail in Chapter Four. The participants were asked to complete the online survey located at the URL (http://hunet.harding.edu/remark4/rws4.pl?FORM=FCGS).

In determining the number of survey responses needed to enhance the credibility of the study, Gay, Mills, and Ariasian (2009, p. 133) state that if the population being investigated is beyond a certain point (N = 5,000), the population size becomes irrelevant and a sample size of 400 is adequate, and if a larger sample is used, an even higher confidence in the study results. The population size of female computing graduates is unknown but is certainly larger than 5,000 based on the number of computer and information science degrees conferred on females in the school year 2007-08 which was 6,782 (Snyder & Willow, 2010). Therefore, this study tried to achieve a quota of 400 survey respondents within a reasonable time frame. Gathering this amount of survey data proved to be arduous, and after five months of seeking participants, survey data collection ceased after receiving 210 submissions.

Phase II: Interview Method – Qualitative Data Collection

To support the results from the quantitative phase (Creswell & Clark, 2007, p. 24), interviewees were selected from the survey respondents who indicated on their survey a willingness to participate in an interview exploring further their decision to pursue a computing degree and their perseverance to finish it. The qualitative phase used

purposeful sampling (Creswell, 2003, p. 219) by selecting individuals whose responses would lend support to the quantitative findings (Creswell, 2003, p. 16). The interview questions were not developed until after the quantitative data had been analyzed and conclusions formed.

Two research studies using both the same research methodology (sequential explanatory) and specific research methods (survey followed by interview), as this study, offered insight into how many individuals should be interviewed after the quantitative phase (phase I). Hodgbin (2008) received 1,431 responses to a survey and set a quota for six qualitative interviews to support the quantitative findings but conducted six more to ensure better confirmation. Sosu, McWilliams, and Gray (2008) collected 193 survey responses and interviewed eight during the qualitative phase to endorse the quantitative findings. Using these studies as a basis for determining the number interviewed, this investigation set a quota for a minimum of six interviewees.

Instrument Development and Validity

Survey Development

The *Female Computing Graduate Survey* was created using Remark Web Survey Software by Gravic, Incorporated (Gravic, 2012). This software tool served the following functions: 1) building and web-posting the online survey form, 2) automatically uploading participant responses to a web server, and 3) performing some descriptive data analysis. The functionality provided by this tool enabled the survey portion of the study to be performed with improved efficiency and reliability.

The survey contained 39 questions and statements requiring a response (37 closed-ended and 2 open-ended). Specifically, the survey was divided into four categories and placed in the following order: 1) demographic information, 2) factors that might contribute toward pursuing computing study, 3) factors that might help one persist in the computing major, and 4) a request for interview volunteers.

To begin the survey, one initial question was asked to help guarantee that only females who received an undergraduate computing degree completed the survey. Those respondents who were not computing graduates were informed that since the survey was intended only for graduates, they did not need to complete it.

Category one contained four demographic questions which were used to describe the respondents when the study findings were reported. Information was obtained on the type of computing degree conferred, year computing degree was obtained, the state location (i.e., Alabama, Arkansas, etc…) of the degree-granting institution, and the state location of pre-college education.

The second category of questions (6-14) focused on factors that might influence a woman's decision to pursue a computing education. Questions 6, 6a, and 6b asked the respondent if she took any computer programming courses prior to enrolling in a computing major, when she took the first programming course and her level of enjoyment in the courses. Research indicated that simply taking and enjoying a computer course, particularly programming, can contribute to female interest in computing and eventual enrollment in a computing course of study (Buzzetto-More et al., 2010; Margolis & Fisher, 2002; Tillberg & Cohoon, 2005; Varma, 2009; Yashuara, 2005). Questions 7

and 8 focused on the skill level in and enjoyment of mathematics based on research asserting that mathematics is foundational to computer science (Denning, 2005) and that an enjoyment of and adequate preparation in mathematics are usually found in female CS students (Tillberg & Cohoon, 2005; Yashuara, 2005). Questions 9 and 10 sought to determine when a female first experienced an interest or fascination with the computer, and when did she become interested in pursuing computer study. Holmes (2011) wrote that female interest in computer-science starts young; the survey attempted to find out how young. Literature could not be found that examined when the desire to study computers surfaced. Questions 11 and 12 queried two additional areas believed to have an impact on a woman's decision to engage computing study: 1) did she possess an accurate understanding of what she would be learning in the field of computing before enrolling (Carter, 2006; Margolis & Fisher, 2002; Teague, 2002), and 2) did self-confidence in her ability to excel in the major exist before enrolling (Beyer et al., 2003; Moorman & Johnson, 2003; Papastergiou, 2008; Singh et al., 2007). Question 13 asked about the relative importance of several intrinsic and extrinsic factors that have been shown to direct a woman toward computing (Howles, 2007; Potter et al., 2009; Ryan & Deci, 2000a; Ryan & Deci, 2000b). Question 14 concluded this section and was open-ended, allowing the respondent to freely state why she *ultimately* decided to pursue a computing degree. The question was asked here because the other questions in this section had hopefully stimulated her thought process, causing more reflection on why she chose a computing major. A few pilot testers mentioned that reflection is exactly what happened to them because they had never thoughtfully considered the different factors that may have influenced their decision to pursue a computing major.

Questions focusing on factors that contribute to persistence in the computing major formed the third category of questions. Questions 15, 16, and 17 tried to find out the relative difficulty of the major from an academic, social, and cultural perspective. Many studies indicated that males and females experienced equal academic success rates, which aided persistence (Singh, et al., 2007). However, the social and cultural aspects of computing programs have made persistence difficult for many women (Ali, 2009; Seymour & Hewitt, 1997). Question 18 asked the relative importance of many factors found to be related to female persistence in computing (Barker et al., 2009; Black et al., 2011; Cohoon & Aspray, 2006; Dee et al., 2009; Dweck, 1999; Katz et al., 2006; Lewis et al., 2008; Margolis & Fisher, 2002; Seymour & Hewitt, 1997; Teague, 2002; Varma & Lafever, 2006) . Question 19 closed this section with an open-ended question asking the respondent to personally reflect and indicate how she was able to *persevere* and *finish* the major. With the exact same reasoning as question 13, question 19 was asked here because the respondent had just finished answering questions regarding perseverance, and hopefully, the questions made her re-consider how she was able to complete her degree and to articulate her path to a successful finish with better accuracy.

The final section of the survey began with question 20 and asked the respondent if she would be willing to be subject to an interview exploring in depth her decision to enroll in computing study and her ability to persevere and finish the major. A textbox was provided in Question 21 to state her name and a best means of contact if she was willing to be interviewed.

Validity

A survey instrument is usually considered valid if it measures what it is supposed to measure (Backstrom & Hursh-Cesar, 1981). The majority of the questions in the survey focused on reasons that might explain how a woman pursues and finishes a computing degree. If the questions in the survey address some aspect of these two issues (pursuit and perseverance), then the instrument exhibits content validity and confirmation can be established by expert judgment (Gay, Mills, & Ariasian, 2009). Four experts on the subject of female underrepresentation in computing academia were consulted and offered their analysis and suggestions for improvement in a two-hour focus group session. The four experts were professors of computer science at a medium-sized (6,000 students) university in the southwest portion of the United States. Each professor had at least ten years of teaching experience in computer science, and they were all keenly aware of the difficulty in recruiting female students into computer science and encouraging them to stay once they were enrolled in the major. The focus group session was recorded and several changes were made to the survey, particularly in the wordings of questions and answer choices. The experts all agreed that with the modifications suggested, the survey would address the two main issues under investigation. To further establish the content validity of the survey, a pilot test was performed on the instrument (Creswell, 2003, p. 158; Gay, Mills, & Ariasian, 2009, p. 181). Five female computing graduates, who were not participants in the study, were asked to complete and critique the survey. Suggestions for improvement were noted and changes made where necessary.

Cross-reference of survey variables with research questions

Creswell (2003, p. 159) suggested the creation of a table that related the variables of the survey to the specific research questions, which demonstrated how the survey questions were used. Table 2 lists each of the eight research questions, and Table 3 cross-references each survey variable with the research question it addressed.

Table 2: Research questions

Research Questions
1. What percentage took a programming course before pursuing a computing major, and if so, when was it taken and what was the enjoyment level?
2. Before beginning a computing major, what was the level of math skill and enjoyment, and was math a factor in pursuing computing?
3. At what time did an interest or fascination in computers first occur, and at what time did the thought of pursuing a computing education occur?
4. What percentage understood what they would be learning in their computing major before enrolling?
5. What percentage was confident in their ability to excel in the computing major before enrolling, and for those not confident, why did they choose to pursue computing?
6. What extrinsic, intrinsic, and other factors were most important in deciding to pursue computing study?
7. Did the academic, social, and cultural atmosphere of computing make perseverance difficult?
8. What factors were most important in encouraging persistence until degree-completion?

Table 3: Cross reference study variables with research questions

Survey Item#	Variable Name	Research Question	Type of Question
6	PriorProgramming	1	Closed
6a	WhenFirstProgCourse	1	Closed
6b	ProgEnjoyment	1	Closed
7	HighestMathCourse	2	Closed
8	MathEnjoyment	2	Closed
9	FirstInterestAge	3	Closed
10	ConsiderComputingAge	3	Closed
11	UnderstandWhatWouldBeLearned	4	Closed
12	ConfidenceToExcel	5	Closed
13a	Pursue-EnjoymentOfComputers	6	Closed
13b	Pursue-EmploymentOpps	6	Closed
13c	Pursue-ComputingSeemedInteresting	6	Closed
13d	Pursue-IntellectualChallenge	6	Closed
13e	Pursue-SkillDevelopment	6	Closed
13f	Pursue-PersonallyRewarding	6	Closed
13g	Pursue-Encouragement-e	6	Closed
13e	Pursue-ChallengePerception	6	Closed
13f	Pursue-WellPayingJob	6	Closed
14	WhyPursueComputingIOW	6	Open
15	AcademicDifficulty	7	Closed
16	SocialDifficulty	7	Closed
17	CulturalDifficulty	7	Closed
18a	Persist-MakingFriends	8	Closed
18b	Persist-Collaborate	8	Closed
18c	Persist-AcademicSuccess	8	Closed
18d	Persist-FacultySupport	8	Closed
18e	Persist-Relevance	8	Closed
18f	Persist-FemaleRoleModels	8	Closed
18g	Persist-Encouragement	8	Closed
18h	Persist-SeeingPurpose	8	Closed
18i	Persist-WomenCanSucceed	8	Closed
18j	Persist-StressManagement	8	Closed
18k	Persist-WorkEthic	8	Closed
19	KeysToPersistenceIOW	8	Open

Format for Providing Results

In the survey, there were 32 closed-ended (quantitative) and 2 open-ended (qualitative) variables used to store survey data critical to answering the research questions. The quantitative results were reported using descriptive statistics, specifically frequencies and percentages. The two open-ended variables were reported by listing predominant themes and their associated frequencies. The descriptive statistics were combined with the predominant themes and portions of interviews conducted in the qualitative phase to provide the results for each research question.

Resource Requirements

The resources that were needed to implement and complete the study are listed in Table 4. There were three categories of resources: 1) computer hardware, 2) computer software, and 3) people.

IRB Approval of Study

The Institutional Review Boards (IRB) of Harding University and Nova Southeastern University approved the study outlined in this chapter. Documentation proof is found in Appendices C through E. Additionally, informed consent forms were signed for the interview phase of the study by the interviewees. This consent form was approved by the Nova IRB, and a copy is provided in Appendix F.

Table 4: List of resources needed to perform the dissertation study

Hardware	Purpose
PC Laptop	Writing, storing data, running software, literature searches, accessing Internet, email
Desktop computer	creating the survey, accessing and analyzing the data collected
Computer server	Backup data, writings, and literature
External hard drive	Backup data, writings, and literature
Audio recording device	Recording interviews with research participants

Software	Purpose
End Note X3	Maintaining annotated bibliography
Microsoft Word	Document writing
Microsoft Excel	Organizing data in row/column format and performing data analysis
Microsoft Visio	Drawing diagrams and processes
Digital Voice Editor 3	Transcription of interviews to text
Remark Web Survey	FCGS creation, publishing, data collection and data analysis

People	Purpose
Research Participants	Survey and interview participants
Topic experts	To critique and validate the survey
Pilot testers	To critique and validate the survey
Document proofing	Proof report for grammar, spelling, APA guideline adherence, and clarity in presentation.

Summary

To better understand how a female determines to pursue a computing major and persists in it until a degree is received requires insight from those who have had the experience. A female computing graduate is such a person who would possess this

insight. A sequential explanatory or QUAN -> qual methodology was used to answer the eight research questions posed. The first phase of the study obtained survey responses (quantitative data) from a sample of female graduates in regard to their decision to pursue a computing degree and how they persevered once they were enrolled. The data was analyzed and conclusions derived. After this process, interview questions were developed, and a few of the survey respondents were purposefully selected to participate in an interview. These interviews were designed to confirm and explain in more detail the findings from the survey phase. This study design appeared to be an excellent way to acquire answers regarding a woman's pursuit and completion of an undergraduate computing degree.

Chapter Four
Results

Introduction

This chapter presents the results based on data collected in two distinct phases. The data-collection instrument for Phase I was an online survey (Appendix B). Of the 210 survey responses, only 160 were determined to be useful. The non-usable responses were from women who did not possess an undergraduate computing degree or whose degree-granting institution was outside the United States. The answers to the research questions had to originate from women who possessed a computer-related degree and from a college or university in the U.S. Phase II data was obtained via interviews with six women who had completed the survey and were willing to answer questions intended to probe deeper into their reasons for pursuing a computing education and persisting within it. Interview segments and quotes are included when necessary to add helpful information when presenting the final results for each research question.

Participant Demographics

The 160 survey respondents represented 21 different computer-related degrees, with the majority holding a degree either in Computer Science (56%), Information Systems (17%), or Management Information Systems (9%). Responses were submitted from at least one female degree-earner in every year between 1990 and 2012, with the

most responses (11) coming in the years 2000, 2009, and 2012. There was not a representative from 1989, three from 1988, and 29 responses from those who graduated before 1988. Female computing graduates representing institutions from 30 out of the 50 United States completed the survey, with more than half receiving the degree from a college or university in Arkansas (51), California (14), Missouri (12), or Pennsylvania (12). Additionally, data was collected on the states where these graduates experienced the majority of their pre-college education, 31 states were represented, with the highest frequencies being Arkansas (39), California (13), Texas (13), and New York (10). The demographic data demonstrated a participant base that possessed a wide array of computing degree types, had graduates spanning more than 24 different years, included degree holders from many different states, and contained women who were raised in various locations throughout the Unites States and abroad. A complete demographic breakdown of the participants can be found in Appendices H - K.

Obtaining Survey Participants

Collecting the survey responses took approximately five months. The participants in the study came from the following sources:

- Women who worked for businesses that sent them the survey link (either by email, LinkedIn, Facebook or Twitter)
- Women in computing professional societies geared toward females
- Twitter users who responded to various postings mentioning the *Female Computing Graduate Survey* and the need for participants
- Computing degree alumni at one institution in the Midwestern United States

- Women in the population who were contacted by a friend or colleague who knew they fit the desired population

Research Question One

What percentage took a programming course before pursuing a computing major, and if so, when was it taken and what was the enjoyment level?

Studies have shown that a positive introductory programming experience is a key factor in leading a woman to pursue computing study at the college level (Dee et al., 2009; Margolis & Fisher, 2002; West & Ross, 2002). However, many students, because of a deficient high school computing curriculum, never have the opportunity to experience a computer programming class (Carter, 2006; Varma, 2009) and therefore are unable to decide if a future education in computing would be worth considering. Because of the apparent importance of programming in attracting women to computing, a series of survey questions were asked to learn more about their initial experience with programming.

Approximately 57% of those responding reported that they did have a programming course before beginning a computing major. Within this group, 49.5% indicated that the programming course was taken during their high school years (10^{th}-12^{th} grade), and almost one-third (32%) had their first programming course in college. Regardless of when the programming course was taken, *enjoyment* of the programming class was rated as medium, high, or very high for just under 96% of the women with close to one-half reporting "very high." This result supports the importance of a prior,

enjoyable programming experience to attract a woman to computing. Here are quotes from four of the respondents (emphasis mine):

> I started out as a pre-med major desiring to become an orthopedic surgeon. I decided against it because I knew I would miss out on a lot if and when I decided to have a family. Thought I would like accounting, because I liked math and structure. Hated accounting. *But during that period, I took an exploratory computer class which included some basic programming that I really enjoyed. So I began my pursuit of a computing education*.
>
> My husband received an undergraduate degree in MIS. Once he graduated, I returned to college to pursue the same degree. *I had enjoyed my first programming class so I decided to pursue an MIS degree*.
>
> I REALLY enjoyed programming. When I was a kid, I had decided I wanted to be a programmer pretty early. Later, I strayed off the path (into electrical engineering), but all of my dull engineering courses had me missing the sort of fun problem-solving I did when I was programming. *I ended up switching to computer science, and doing what I wanted to do when I was a kid*!
>
> *After taking two programming courses in high school I decided that programming is something that I could enjoy doing on a daily basis*.

The lack of a prior course in programming is evidently not a strong deterrent to pursuing a computer-related degree for many women, as 43% of the respondents stated they had no programming course before beginning a computing major. However, as seen in the following excerpts from two interviews, the first programing course experience, once a student is enrolled, is crucial in helping a woman decide whether or not a computing education is the right academic path for her.

> [Note: The interviewer portions are in bold throughout.]
>
> (Interview One)
>
> **So you changed majors three times in college so that's not unusual. But here's my question, when you took your first programming course, what was your experience?**

> *I loved it!* It seemed really natural to me, and it was very apparent early on in the class *that I finally picked the right major.*
>
> **Did you feel like programming was just a good fit for you? Was programming the course that gave you the idea that, yeah, this is what I want to do?**
>
> *Yes, yes!!*
>
> (Interview Two)
>
> [After switching from Pre-Law to Information Systems]
>
> **Okay, so tell me, in your first, introductory programming class, what was your experience with it?**
>
> Um, it was eye-opening to understand that it's basically problem-solving, as far as building a program that solves a problem. I liked doing that part, *so I was attracted to having something that you're trying to achieve and how you get there with using the language you have available*.
>
> **So when you took that programming course, did you feel it fit your talent, area of interest, and enjoyment?**
>
> Yeah, I mean it was fun …. I wouldn't say entertaining, but it wasn't work.

The results strongly suggest that having a positive experience in an introductory programming course, either prior to starting a computing major or in the initial stages of the major, was a common factor leading women to desire a computing education. Data analysis pertaining to the primary programming course experience of the respondents can be found in Appendices L – N.

Research Question Two

Before beginning a computer-related major, what was the level of math skill and enjoyment, and was math a factor in pursuing computing?

Men and women both enjoy the math and logic component of computing. Research conducted by Tillberg and Cohoon (2005), and Yashuara (2005) report that women more frequently cite math and logic as a reason for enjoying the field and continuing in it. This research question tried to uncover if there was a level of math skill and enjoyment common among these female computing graduates when they began the major. Also, might math skill and enjoyment lead a woman to study computing?

In response to the question asking about the highest level math course taken before enrolling, slightly over 75% reported that they had taken at least a pre-calculus or higher math course. An expressed enjoyment of math before starting computing was found in 77% of the women. Did math, however, serve as a factor for leading these women to consider a computing education? The following two interview segments provided evidence that math was a factor.

(Interview One)

Do you think math in any way was one of the primary reasons that you decided to pursue computing?

Well, yes, certainly. I didn't know going into it but I was told by a guidance counselor in high school if you're good in math, if you enjoy math, you might enjoy computer science. And so certainly that drew me into it. Uh, it's hard to say how much of my actual math education really came into play in getting my computer science education. It's hard to say I really needed calculus to be able to pass assembler programming … no, I really didn't! But the math background, the math enjoyment, the left-brain, right-brain thing … if you enjoy math, you probably enjoy problem-solving. I guess I would make that connection.

So, you *would* make that connection?

Sure, and with a logical method of problem-solving. Not just tell me your problems and I want to solve them for you but through some meaningful, logical, step-by-step type of analytical process and I enjoyed that. I guess that's why I enjoyed algebra so much and calculus so much.

There's a logical, systematic approach to solving problems basically?

Well, once I understood that's what computer programming was all about, was solving a problem in a logical, mathematical or orderly type of analytical way. That's where the relationship to math comes in … Being good at one (math), I believe certainly would indicate you might be good at the other (computing), especially, if you enjoyed it. If you were good at it (math) but didn't like it you probably wouldn't care for computer science a whole lot.

(Interview Two)

Math has been shown in some studies to direct a woman toward computing and my question to you is: was this true for you and how so?

Um, yeah, absolutely! In high school, well, all the way back to elementary and middle school, I was good at math. I enjoyed math and I took the advanced courses they had available. In high school, I continued that by taking AP calculus my junior year and multivariable calculus and differential equations my senior year. While these classes didn't wind up being directly related to computer science or software engineering, *that strong math background gave me the confidence to take technical classes and to make me feel like I belonged there*."

The results affirmed that a majority of women in this study had a strong background in and enjoyment of math. Qualitatively, it was revealed that math can provide an impetus to consider a computing education. The logic component, inherent in mathematics, was viewed as important in computing, particularly in programming, and enabled one to experience success. Interestingly, a high level of math skill, such as calculus, does not seem to be necessary in order to understand computing, but it does appear that having taken and enjoyed advanced math courses builds an inner confidence that increases the self-belief that one can excel in computing. For a complete view of the statistical data associated with math skill and enjoyment, see Appendices O and P.

Research Question Three

At what time did an interest or fascination with the computer first occur, and at what time did the thought of pursuing a computing education occur?

Interest in any science field for women, including computing, starts young (Holmes, 2011). Young children are sparked toward an interest in computers, especially by parents who fuel their enthusiasm toward computers (Margolis and Fisher, 2002). Apparently, it is possible that this early interest in computing when young, can be lost as one gets older, and by the time some women reach senior high school (11^{th} – 12^{th}) the interest is non-existent. Anderson et al. (2008) found that most 11^{th} and 12^{th} grade females did not take computer-science courses because there was a high degree of non-interest in computers. These studies bring to light two interesting questions: 1) when is the time period where interest in computers first arises and 2) for this sample of female computing graduates, when did they first experience an interest in studying computing?

The survey data shows that initial interest or fascination with the computer happens most frequently during kindergarten-5^{th} grade (23%), 10^{th}-12^{th} grade (22%), or college (32%). Interestingly, initial interest was highly uncommon from the 6^{th} through 9^{th} grade. An interest in pursuing an education in computing for over one-half of the respondents (52%) did not occur until college, while approximately one-third (32%) of the responses showed that interest happened between their 10^{th} and 12^{th} grade years. Why did more than 50% of the respondents wait until college to consider a computing education? Based on interviews, it seems that the answer might possibly stem from a common occurrence found in answers provided from women who graduated in different

decades. In the responses to the interview question as to why you waited until college to consider a computing education, there is a common thread of *unawareness of computing education and if I knew something about it, might it interest me?* If these women had possessed a true understanding of computing and what is involved in it, the decision to pursue computing might have been made before college.

Portions from three interviews follow. Interview one gives an example of a woman who had some experience in computing but never considered it as a viable academic major in college. Upon entering college with engineering as her declared major, she learned about the exciting discoveries being made in the computing field and soon switched her major to computer science and earned a degree. The second interview portrays a woman who was vaguely aware of the field of computing in high school only because a few computing courses were offered. These courses were never publicized or pushed, and they seemed to be catered to a select few who already were interested in the subject. Therefore, she didn't take a class in high school and never realized that she would, in college, find the field fun and eventually begin and finish a computing major. The final interview illustrates an individual who quit one major with no idea what to do next. She decided to take a chance on a computer-related major, not because she knew anything about computing, but because her father was in the field and she was good at math. It turned out to be a good gamble because she discovered a noticeable amount of enjoyment in the major and finished with a degree in the field.

> (Interview One – graduated computer science in1988)
>
> Yeah, I started programming in high school but my plan was to be an electrical engineer so that is what I was planning on doing when I went to

college. I never thought of computing. When I started college back in the 80's PC's weren't on every desk yet. It (computing) wasn't really something I looked at doing but while I was in college, all sorts of things were invented. Everything from the graphics card to mice was invented. You know, computers started to be everywhere and it became more enticing than someone who was locked in a cold computer room…It was kinda cool to see so many developments and I beta tested X-windows and all these new things were coming out. One of our finals was how would you write a mouse and there weren't mice yet. And it (computing) was opening up and there were so many possibilities … there was natural language processing, artificial intelligence. It was very exciting!

So, you switched from EE to CS because you thought it was cool, exciting, brand new, and you wanted to get in on the ground floor. Did I characterize your reason for switching to CS correctly?

Oh, yeah! It was definitely more exciting than electrical engineering for me. You know I had friends who thought electrical engineering was the most fabulous thing and we would argue about it. They would go "EE is so cool" and I would go "NO … NO.

(Interview Two – graduated information systems 1997)

Slightly over half of the respondents in the study did not consider an education in a computing field until college, and that was you. Why was this true for you?

In high school, I graduated in 1993, there wasn't a lot of programming … or classes available at my high school. Maybe a couple but at the time I wasn't considering it. I was looking into being a lawyer and so I was pursuing that path. There wasn't a lot of it (computing courses) and it wasn't publicized or something they (teachers and administrators) pushed. I think it was for the kids who had interest in it to begin with.

(Interview Three – graduated information systems 2007)

You didn't consider computing until college and I was wondering why that was true for you because I want to understand why women wait to decide they want to do computing in college?

Well, I was pre-dental before and I quickly realized my first year of college that the only reason I liked chemistry was because I was good at the math part of it. When I got to organic chemistry and other stuff, like, I don't get this stuff and quickly realized it. I had no idea then what I wanted to do. My father was in the (computing) industry so I sat down that summer and I was thinking that I think like my father and he's very good at math so I was thinking like maybe this (computing) could be something I could do and didn't put much more thought into it other than

> that. And so I took a chance and I was very surprised that I actually enjoyed it and was good at it.

The findings support previous research asserting that interest in computers for women can start fairly young, but this study shows that initial interest may also be kindled in high school and college. Becoming interested in pursuing a computing education; however, most often occurs once a woman enters college, not before. The survey data associated with interest in computers and interest in computing education can be found in Appendices Q and R.

Explaining why more than 50% of the women in this survey indicated they waited until college to decide to pursue a computing education may possibly be found in a general unawareness of computing education before entering college. Once a woman enters college, there are apparently better opportunities to discover what is involved in a computing education, therefore placing her in a better position to determine if this field would be a good fit.

Research Question Four

What percentage understood what they would be learning in their computing major before enrolling?

The mystery of what a computer-science student learns is highlighted in a study by Carter (2006), who asked high school students what a computer-science major studies, and 80% responded that they had no idea. The other respondents believed that computer science was just about programming and that students basically sit in front of a computer

all day long. Townsend et al. (2007) reported that females believe that a computer-science education will lead to a career spent in front of a computer, in isolation, with no chance to interact or work with others. All of these studies report results indicating that there exists a vast misunderstanding of the educational environment within a computing major. This research question sought to find out the extent of pre-enrollment misunderstanding that existed among this sample of graduates.

The results from this question showed that 57% agreed with the statement: *"Before enrolling in a computing major, I had an accurate understanding of what I would be learning in the major*." However, 43% disagreed with the statement, which demonstrated that there were women who pursued computing study even though they had a poor understanding of this academic field. Appendix S provides the statistical breakdown for this question.

An interview question was developed to address, why a woman would pursue a field where she had a dearth of understanding in regard to what would be studied and learned. It appeared that encouragement and advice from significant people, the perceived challenging nature of the field, a math connection, and a belief in a bright future in the field are primary in deciding to enroll in computing despite an inadequate understanding of the discipline. Two interview replies and four participant comments to the open-ended question "*Why did you ultimately pursue a computing education?"* provide some insight.

(Interview One)

When you left high school, you went to college and had to pick a major, and you decided it would be computing. You put on your survey that it was a complete leap of faith. Is that correct?

(Laughing) I had no idea about computing.

Yeah, you had no idea but what urged you or made you go in that direction. You have mentioned math (previously) and a leap of faith. Would that be the two reasons you decided on computing?

And, the guidance counselor. Yeah, the guidance counselor said I think you'd be really good at this, I think this has a future, this is an education that should be able to get you a good job. There's a lot of demand for it. It's growing. You know, she was probably more of a visionary about it and had a better idea of what she was steering me toward than I had.

(Interview Two)

My question is why did you decide to enroll in the field of computing even though you had very little if any knowledge about what you would be studying and learning?

I was attracted to the idea of computing because I had a few applications classes (in high school) and you don't know what something is going to be like until you try it, and I was a freshman when I entered the major (information systems) and I knew I still had time to change if I got into it and didn't like it.

So, you really just wanted to give it a shot.

Yes.

Was there anything you were looking for or getting out of it in terms of enrolling… things that would help you or was it just something that you tried on a whim? Were there any other factors involved?

Financial reasons. I knew getting a degree in that field gives you good job possibilities.

So your perception was if I go this route then at the end of the road then I'm going to be looking at a pretty good career and it's going to be financially rewarding and other good things?

Right! Whenever I threw pre-law away I wanted to find something else that would at least be financially stable."

(Comments)

"I tried Accounting when I first got to _____ and discovered that it just wasn't for me. When deciding what to do next, I knew it had to be something that challenged me, and programming seemed like it would

> offer that challenge. Plus it was an entirely new world with an unlimited amount of things to learn."
>
> "It was the only major at my college that required me to take many math courses. Since I didn't want to major in mathematics, I thought computer science would be the next best thing. I also looked through an Occupational Outlook Handbook in high school; System Analyst was one of ten job titles I picked."
>
> "I knew I wanted a business degree before attending law school, but was undecided as to which one. I very much trusted my adviser's judgment, and he suggested I try MIS. Not only would it give me core business classes, but would put me in a very good position for law school. (And, he added, if I changed my mind on law school, it would set me up in an excellent position for getting a job.) I knew nothing of programming, but when I heard few women were in the major - I took it as a challenge. With much encouragement from my family, I finished with a 4.0 in my major and as one of the top 2 MIS students in my graduating class. Law school actually did get put on hold when I got married, so I took a programming job and have been doing this ever since."
>
> "I could not make up my mind, someone told me I was good with math, I should try computer science. I took one class, and I was hooked. I found that computer programming was like a game, nothing like work. I knew it was the field for me!"

Slightly more than half of the women agreed that they understood the academic nature of a computing education and therefore were able to make an informed decision to pursue this academic discipline. A surprising percentage (43%) reported that they did not have an understanding of what is taught and learned, which raised the question - *Why did you enroll given this lack of understanding?* Through interviews and textual analysis of open-ended responses on the survey, it was revealed that the factors of encouragement and wise advice from others, a challenging field, the correlation to math, and a hope for a bright future in the field are crucial in attracting uninformed women to the field.

Research Question Five

What percentage was confident in their ability to excel in a computing major before enrolling, and if confidence was not present, why pursue computing?

Low self-efficacy (a person's judgment about her ability to carry out a goal) among women in regard to computers and in introductory computing classes serves as a major disincentive to study computing and persist in it (Beyer, et al., 2005; Powell, 2008; Singh, et al., 2007). Papastergiou (2008) states that self-efficacy is positively related to a woman's intention to study computer science. This question sought to discover what percentage possessed an initial confidence, and to investigate the reason why someone would pursue computing if she *did not* have confidence.

Seventy-nine percent of the respondents indicated their agreement with the statement: *"Before enrolling in a computing major, I was confident in my ability to excel in the major."* However, the majority of those agreeing with the statement (52%), did not indicate a "strong" agreement. Only 27% indicated a strong agreement with the statement. Interestingly, 21% did not agree, indicating low self-efficacy before enrolling. Appendix T provides the percentage breakdown.

Why would a woman, low in self-efficacy in regard to computing, decide to pursue a major in the field? From one woman's perspective, it seems that initial, humble attitude plays a major role in the decision.

> **I asked this question or statement on the survey and it went like this: Before enrolling in a computing major, I was confident in my ability to excel in the major." You disagreed with this statement. You were not confident. Why did you decide to enroll in computing despite being unconfident?**

> Well, I am unconfident and confident in every aspect. In anything I start, I always start with expectations of myself low and then I just try hard to push past it.
>
> **I'm curious, you started off unconfident, did your confidence gradually increase and why did it increase if it did?**
>
> It did because when I got into the classes, I figured out I understood what they were talking about. I was able to learn and apply it and make good grades. The main thing was I understood. Whenever they would introduce a new concept, I understood what they were talking about and I could achieve it. So, going through the classes and being able to do it built up my confidence."

Approximately four out of five women surveyed recalled that they were confident in their ability to excel in a computer-related major *before* entering the major. This suggests that high self-efficacy is important in making a decision to pursue the field. Based on the interview, it also appears that self-efficacy levels may still increase for those who enroll with a low efficacy level and thus result in better persistence.

Research Question Six

What extrinsic, intrinsic, and other factors were most important in deciding to pursue computing study?

There were two parts to this question. Part one focused on nine extrinsic and intrinsic motivating factors that have been discovered through research to direct a woman toward computing. The respondents were asked to indicate the relative importance a particular motivator had in their decision to pursue. Part two allowed the respondents to describe in their own words why they ultimately decided to pursue computing. The open-ended question was provided, assuming that the motivators in part one were not all-

inclusive for the possible myriad of reasons why a woman decides to engage this academic field.

Part One Results – Extrinsic and Intrinsic Motivating Factors

Results for each motivating factor in part one will be presented first, followed by a sorted listing of factors ordered by importance. The relative importance of a factor, as compared to the other factors, was determined by the percentage of respondents indicating the factor was *"very important."*

Factor One: My enjoyment of computers and technology (INTRINSIC MOTIVATOR)

For men and women alike, the pure enjoyment from working with computers and technology was a motivator for pursuing computer science (Margolis & Fisher, 2002; Yashuara, 2005). The enjoyment of computers and technology was rated as very important to 59% of those responding, while only 3% indicated this factor was non-important.

Factor Two: The availability of excellent employment opportunities after graduating with a computing degree (EXTRINSIC MOTIVATOR)

The motivational importance of future career opportunities for women has been reported in several studies (Papastergiou, 2008; Teague, 2002; Tillberg and Cohoon, 2005; Yashuhara, 2005). Sixty-seven percent of those responding to this factor rated it as very important, while less than one percent (0.63%) rated it as not important.

Factor Three: The field of computing seemed to be interesting (INTRINSIC MOTIVATOR)

Several aspects of computing could awaken an interest in the field. The statement does not specifically mention a particular aspect; the statement was designed to discover if the field appeared to be interesting. Ryan and Deci (2000b) state that perceiving an activity as interesting is intrinsic and can strongly motivate one to engage that activity. Sixty-two percent of the respondents indicated that the perceived interesting nature of the field was a very important factor in deciding to pursue computing. Less than one percent deemed this factor as not important.

Factor Four: Believing I was going to be challenged intellectually (INTRINSIC MOTIVATOR)

Ryan and Deci (2000b) state that personal challenge, in this case a personal intellectual challenge, is an intrinsic desire. Dweck (1999) asserts that those who possess a growth mindset do not mind challenges but rather relish opportunities to be challenged, knowing that they will learn and grow from the experience. Fifty-three percent responded that believing the computing field was going to be intellectually challenging was very important, while 3% stated that it was unimportant to them.

Factor Five: The development of skills that would one-day help develop positive solutions for society. (EXTRINSIC MOTIVATOR)

Studies support the belief that for women to be led to computing, they must see a higher purpose behind the field than just computing alone. Women must see the practical, positive application of computing to society (Carter, 2006; Teague, 2002).

Also, Margolis and Fisher (2002) discovered that some women pursued computing because it was the means of fulfilling a higher purpose, such as using computing skills to help another totally unrelated field. Only 24% of the women rated this factor as very important in their decision to pursue computing. The exact same percentage (24%) indicated the factor as non-important.

Factor Six: The work in the major would be personally rewarding (INTRINSIC MOTIVATOR)

Deciding if an activity would be personally rewarding (i.e. gratifying, providing a sense of accomplishment) would satisfy intrinsic desires and motivate one to pursue that activity (Ryan & Deci, 2000b). Believing the computing major would bring personal reward was marked as very important by slightly less than half (48%) of the respondents. Only 1% reported this factor as non-important.

Factor Seven: The encouragement I received from significant people (EXTRINSIC MOTIVATOR)

Tillberg and Cohoon (2005), Kahle and Schmidt (2004), and Teague (2002) all support encouragement as a primary reason for a female deciding to engage computing. Surprisingly, only 23% indicated that encouragement to pursue computing was very important in the decision-making process, while 9.5% responded that encouragement was a non-factor when making the decision to pursue or not pursue a computing education.

Factor Eight: The desire to change the perception that only men can succeed in this field. (EXTRINSIC MOTIVATOR – because the motivator is the changing of an external condition)

Tillberg and Cohoon (2005) found that some females entered computing because they felt the need to challenge societal opinions on the computing field as being a "men only" field. The perception of computing being a field only for men motivated some women to enter computing to prove the perception wrong. A relatively low percentage (16%) felt that changing society's perception was a very important factor in deciding to enroll in a computing major. More than half (58%) indicated the factor was not important.

Factor Nine: A future in computing would be financially rewarding (EXTRINSIC MOTIVATOR)

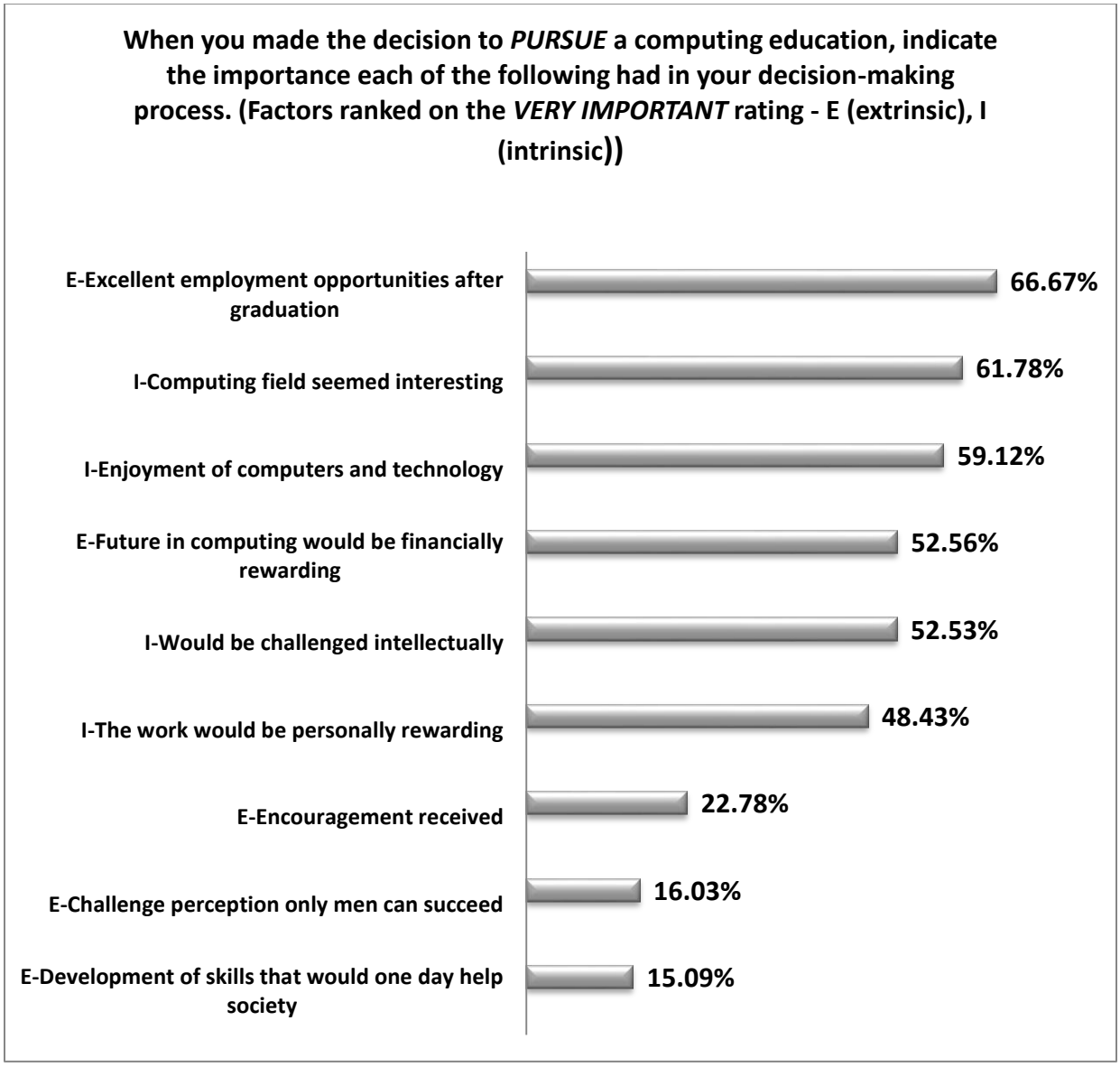
Yashuhara (2005) found that a primary reason for female interest in computing over other majors was income potential. Money apparently is a primary factor in pursuing computing, as evidenced by the 53% of women who marked that this factor was very important. Only 6% designated this factor as not important.

Summary of Part One and the Nine Factors

Part one asked survey participants to rate the importance of nine extrinsic and intrinsic factors in regard to their decision to pursue a computing education. This study found that the top four decision-influencing factors were both extrinsic and intrinsic, with the major factor being an extrinsic motivator (excellent employment opportunities after graduation) and the second major factor being the interesting nature of the field, an

intrinsic motivator. This finding supports Papastergiou (2008), who found that the primary reason young women would study CS was employment opportunities and the second reason was interest in the field. Figure 2 illustrates the importance of each factor in relation to the others. A complete statistical analysis of the importance and non-importance of each factor is located in Appendix U.

Figure 2: Important factors influencing a woman's decision to PURSUE a computing education.



Part Two Results: Open-ended question

The open-ended question: "*Why did you ultimately decide to PURSUE a computing education?"* was asked immediately after the nine extrinsic and intrinsic motivating factors were rated for importance. With the question placed after the respondent examined research-supported factors, she had the chance to articulate why she decided to pursue a computing education.

A total of 153 respondents submitted an answer to this question. Each response was examined at least three times, and the factors identified as directing the respondent to enroll in a computing degree were noted and added to a master list of factors. After textual analysis of the 153 responses, 272 total factors were found resulting in a listing of 51 unique factors. These unique factors were combined further to form a final list of 25 factors. Table 5 displays the final factors arranged according to the frequency of the factor occurring in the responses.

Each of the final 25 factors was placed in one of the following six categories. Factor placement is found in Appendix V:

- Future career and financial benefits
- Appealing aspects of computing
- Intrinsic needs met by computing
- Self-efficacy
- Outside influence
- Other factors

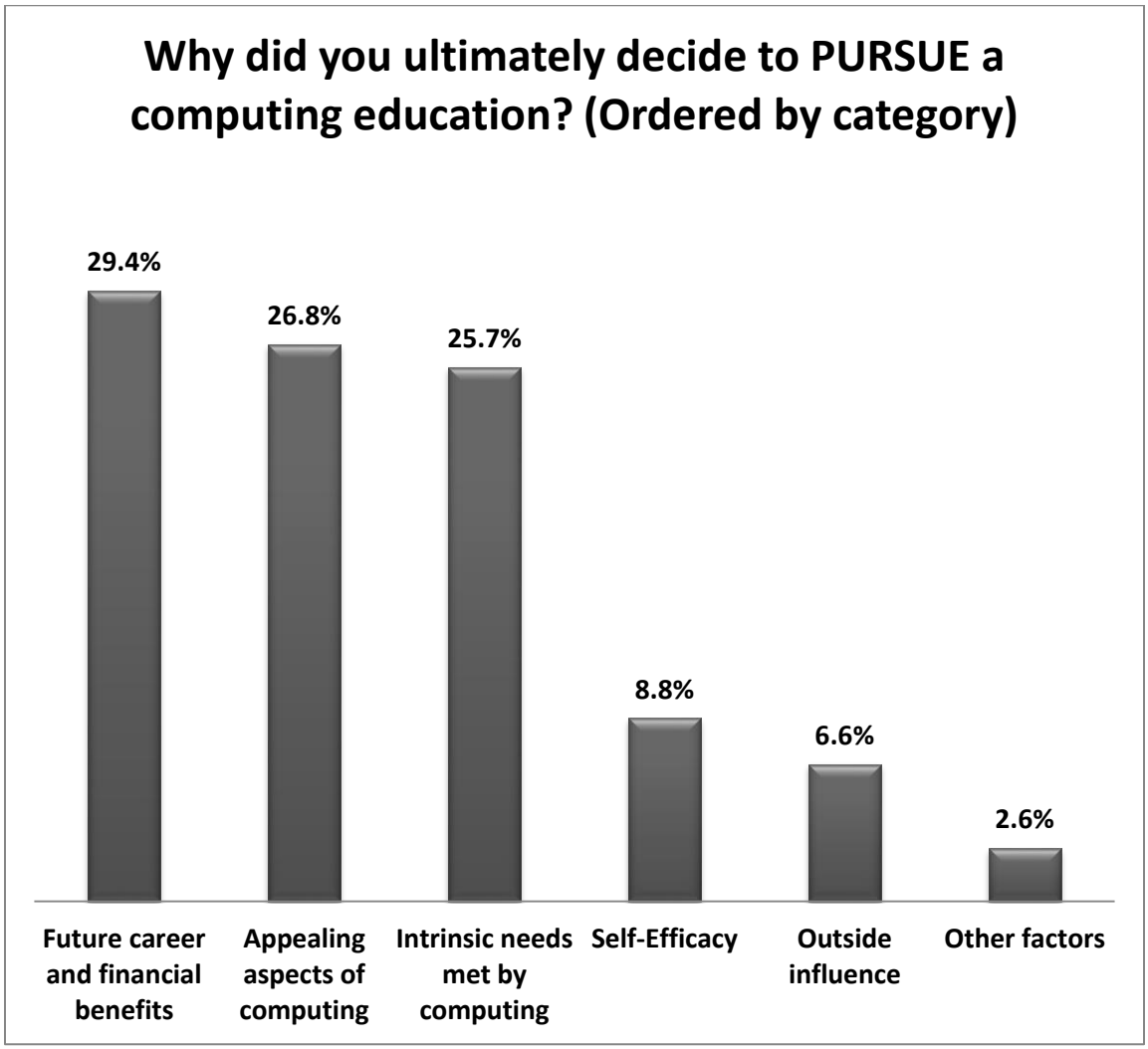
Each category describes a broad reason for a female pursuing a computing education. The percentages associated with a category were calculated by summing the frequencies of the factors belonging to a category and then dividing by the total number of factors

found in the responses (272). This percentage allowed the categories to be ranked in order of relative importance to one another.

Table 5: Factors leading to a female pursuing a computing education (in the respondents' own words)

Factors leading to pursuit of computing education	***Frequency***
Promising and satisfying career prospects	48
Field will provide financial security	32
Programming aspect of computing	31
High self-efficacy - belief that I am or could be good in computing	24
Interesting field	21
Encouraged to pursue computing	16
Field I would enjoy	16
Would provide a challenge	14
Liked computers and technology	14
Problem/puzzle solving aspect of computing	12
Math aspect of computing	11
Logic aspect of computing	7
Wide open and fresh field - always things to learn	6
Creativity aspect of computing	5
Computing was fun	3
Parental pressure	2
Helpful faculty	2
Structured, task-oriented aspect of computing	1
Knew I would be one of few females	1
Lack of other choices	1
Friends were in the major	1
Work was rewarding	1
Embraced the geekiness - felt like I was at home	1
Challenge perception that only men can succeed in the field	1
Class availability	1

Figure 3: Why a woman pursued a computing education (by category)



Summary of Part Two

Analyzing the 25 final factors showed that two extrinsic needs, future career prospects and future financial security were most important. In regard to the appealing aspects of computing, computer programming was found to be a critical factor leading a woman to enter computing study. Finally, the importance of self-efficacy was revealed. The confidence in one's ability to excel in this academic field spurs an attraction to pursue it. When combining the factors into categories, the data shows that future job and

financial considerations, appealing aspects of computing, and intrinsic desires are of almost equal importance. However, self-efficacy should not be minimized as an important category because this category only had one factor; it was the only category where this was true and the reason for a lower importance percentage.

Research Question Seven

Did the academic, social, and cultural atmosphere of computing make perseverance difficult?

For a woman to complete a computing degree, she must be able to manage effectively the academic side of computing. A computing major will challenge one's intellect due to the aspect of problem-solving which is so prevalent in the field. Teague (2002) found that this aspect, which at times can be extremely challenging and stressful, was a major reason why some persisted and stayed in the major. Lewis et al. (2008) investigated how emotions affected perseverance in computer science and related majors and found that those who were able to control their emotions and deal effectively with stress could cope with the daily challenge of a computer-science degree and achieved intellectual growth and academic success.

The survey asked the degree of difficulty academics posed on degree completion. Approximately 60% of the respondents felt that the academics involved in their computing major posed a significant challenge to persevering and completing the major, while only 17% indicated that academics posed no threat to completing the degree. Appendix W displays the percentages associated with level of academic difficulty and degree completion.

Mikesell and Rinard (2011) assert that females are discouraged from considering and persisting in computer science because of the "geek" image associated with it. However, the study found that the social atmosphere posed slight or no difficulty to 75% of the respondents. Appendix X shows the results associated with social difficulty and degree completion. This finding supports the claim made by Margolis and Fisher (2002) that the geekiness normally associated with computing is mostly a myth and that females who stay in computing reject the stereotype of a person in computing being a geek and antisocial (Creamer et al., 2006). The following interview section provided evidence that geekiness is a myth and that computing majors are inhabited with people who are sociable and friendly.

> **You indicated the social atmosphere caused you no problem whatsoever. This is very interesting to my study. I wanted to get your comment why you didn't have a social struggle like, apparently, some women have?**
>
> Maybe I went into it open-minded and didn't perceive that the field was actually a field where people would isolate themselves. I had a few friends in the field or I made friends with people who were going through the field, and they weren't as closed off. It may be that I was lucky and got with particular people who were easy to get along with.

Another reason that certain women may not experience social distress in computing is that the social nature of computing is indeed "geeky." Since this nature is consistent with their own self-image, such students "fit right in." Two women provided insight into this line of reasoning.

> (Interview One)
>
> **Some research indicates that some women will not pursue or continue in computing due to the social atmosphere of computing and I am**

referring to the perceived geek culture, non-social perception, people pretty much are more attuned to themselves than to others or like machines more than people. You indicated the social atmosphere caused you no problem. Talk about that for a little bit.

Sure, when I entered college I was aware of the geeky image, and I thought I would fit right in because of my time on the math team, quiz bowl team, and my time just hanging out with my high school friends. I figured that was consistent with my self-image, and I didn't have any social problems. I felt like the vast majority of people were supportive, and I had plenty of friends who I got along with in my own degree program.

(Interview Two)

You said (on your survey) that the social atmosphere didn't cause you any problem at all. I just wanted you to explain that a little.

Well, I'm not a people person despite the fact that when I go to conferences, I'm very social and connect with other people. I have no problem getting in a room with 500 people and speaking and I'm fine. But I don't like people and I don't want to deal with people and dealing with machines is easy. Also, I was dating somebody all through college who was very supportive, and he was fine with me being a geek. He didn't care. I didn't realize it at the time, but I think I knew there weren't very many women in the classes. But back then, there were a lot more women than there are now.

So, you're saying that this (social nature of computing) didn't cause you much of a problem because one, there were more females at the time, and two, you categorized yourself as a geek who fit in with the geek culture?

I had no problem fitting in as a geek. I really didn't fit in anywhere, so being a geek was normal.

So basically you fit in with the social culture, right?

Yeah, yeah.

However, it should be noted that approximately one-fourth stated that the social environment within the major made completion of the degree moderately to very

difficult. For example, although the social nature was problematic for one participant, she refused to let it negatively affect her.

> **You indicated that the social atmosphere caused you a slight degree of difficulty and I wanted you to explain that a little bit.**
>
> (Chuckling) I'm a very outgoing female and uh, like you said, everybody is reserved.
>
> **So, that was your experience that a lot of people in your major were reserved?**
>
> Yes, and so I came in, loud-mouthed, real friendly, and, I tend to dress differently. I like fashion and stuff like that, so I show up on the first day of school dressed all nice, and they actually asked me when I walked in my first programming class if I was in the right class.
>
> **Really? Just because of what you were wearing?**
>
> Yes, and so I ask, is this CS, intro to programming? And they are like yeah. And I said, well, I'm in the right place then. And it wasn't until the second semester of my junior year before people really accepted me because every semester I showed back up, and they would say, "Are you still here?" They were like mean to me because I wasn't typical. I mean there was one other girl in our classes and she was really into like the computer games they would play outside of class and I was never interested in that and so they thought it was a joke that I was in there. And like I said, it wasn't until my junior year they realized, okay, she makes good grades, she knows what she's talking about, she's in it for the long haul and then after that, everything was perfect. They saw me as an equal at that point.

Tillberg and Cohoon (2005) and Varma (2010) insist that the scarcity of females in computer science is due in part to the cultural perception that it is a male field. Cheryan et al. (2009) suggest that the masculinity associated with computer science causes females to believe that they don't belong. Contrary to these research findings, a large majority (76%) indicated that being in a perceived male domain caused *slight or no difficulty* to their perseverance in the major, with the largest percentage (56%) indicating

this factor caused *no difficulty* in regard to continuing and completing. Appendix Y provides the results associated with cultural difficulty and degree completion.

Two participants provided differing reasons why the male culture did not cause them a problem. For one, it was her self-image, and for the other it was determination and a confidence that allowed her to prove she was more than capable.

(Interview One)

Research has found that some women will not pursue or continue in computing due to the cultural atmosphere of computing, the perception that the field is more suited for men than women and men dominate the discipline. You indicated the cultural atmosphere caused you no problem, and I wanted you to talk about that.

Sure, I actually did, when I was entering college, share the perception that computing was more suited for men and more suited for people who thought logically. The thing is my image at that time of myself was consistent with that, too. I thought of myself as someone who preferred working with machines, thought more logically. I though in more gender-essentialist ways than I do now, and at that time I thought of myself as having more of a male brain than a female brain. And so, seeing mostly men pursuing computing didn't deter me because I thought I do think like them.

(Interview Two)

You indicated that this (cultural atmosphere) did not cause you a problem, and I wanted you to talk about it a little bit.

Well, I guess it does back to the person I was and not being aware of what was going on at the time. It's also why I raced dirt bikes for ten years; men said I couldn't do it, so I did it.

Would you say that you have that inner drive or desire to say "Hey, I can do this, and I don't care what you say"?

Yeah, but I think it was also I knew I could do this (succeed in a computing major), I liked doing it and I wanted to do it. It never occurred to me that they were right in saying that women couldn't do it, and it annoyed me that they thought I couldn't do it, so I was just going to do it, and do it better.

Was the bottom line confidence?

Probably, yeah."

Approximately one out of four respondents stated that the cultural nature did cause moderate to extreme difficulty in persisting. An interesting insight into why the male culture of computing caused one woman substantial difficulty follows. She also gives a powerful testimony that the maleness of computing is a grave problem in some places. The interview response began as she discussed why she started a support group for women computing professionals.

> The reason I did (start a support group) is because women are also leaving. I know you're researching young girls getting into computing, but women are also leaving. The work force is becoming very challenging for the gals that are in their twenties. Very, very challenging for girls in their twenties! I think the issue is the culture of the people in computing. When I was in it (college computing major), the guys liked to play the computer games all night. But there really weren't all these first-person shooters, so I could play these computer games and we had open source computer games. You could play these and you could add to them, program them and do whatever you wanted to them. But now it seems that culture of the guys, I mean I worked at _____ and the guys would come in at night and use the servers to play first-person shooter games. I didn't want to do that so I didn't do it. So, when you talk to some of the younger gals, they're just feeling like outsiders in their own discipline because the guys have all this ton of bonding going on over these kind of games that women just aren't interested in.

The results indicate that academics are the aspect of a computing major that poses the most difficulty for women in their quest to complete a degree. Despite previous research that found the social and cultural nature challenging for females, the majority of participants in this study did not agree and that view is perhaps a factor contributing to their ability to finish. It is recognized that the social and cultural atmosphere was problematic for some.

Research Question Eight

What factors were most important in encouraging persistence until degree completion?

There were two parts to this question. Part one focused on eleven factors that have been found through research to aid a woman's persistence. The respondents were asked to indicate the degree of importance the factor had in their ability to continue and finish. Part two allowed the respondents to describe in their own words how they were able to persevere and finish the major. This open-ended question was provided assuming that the factors listed in part one were not all-inclusive for the numerous possible reasons explaining how a woman continues and completes a computing major.

Part One Results – Eleven Persistence Factors

Results for each persistence factor in part one will be presented followed by a sorted listing of factors ordered by importance. The relative importance of a factor, as compared to the other factors, was determined by how many indicated the factor was *"very important."*

Factor One: Making friends within the major

This factor was deemed critical to women wishing to stay in computer science because it allowed the mutual sharing of the social and academic aspects of life in the field (Katz et al., 2006; Margolis and Fisher, 2002). In evaluating this factor's importance, slightly less than one-third (32%) rated this factor as very important to their ability to persevere and finish while 13% said this factor was not important.

Factor Two: Being allowed to work with others on assignments

Baker, McDowell, and Kalahar (2009) found the most powerful predictor for a student's intention to persist in computing study beyond introductory courses was student-student interactions, and the one practice that fostered this interaction was collaborative opportunities to learn. Barker et al. (2005) examined why computer-science courses had high attrition of women, and they noted lack of collaboration permitted in the classes as a possible reason. The rating of this factor found 23% believed it was very important and 22% indicated that collaboration was not important.

Factor Three: Academic Success

Katz et al. (2006) observed that women are more keenly attuned to their academic success than men, a trait that affects persistence in the major. They reported that if a female made less than a B in her first computer-science course, she was more likely to drop out than a male who made less than a B. This factor was found to be the top-rated factor by those responding with 65% reporting it was a very important factor. Not a single respondent rated academic success as non-important.

Factor Four: Faculty Support

Research findings are scarce on the importance of faculty in aiding the retention of female students in CS, but in other sciences such as engineering, math, and biology, studies reveal a connection between faculty and student retention. Adkins (2007) found that having female faculty in a field is helpful in attracting women to an academic field. However, in regard to persistence, the gender of the faculty member is not as critical to students as simply having their needs met (Seymour & Hewitt, 1997). Cohoon et al.

(2008) found helpful and caring advice received from faculty in a computer-science doctoral program was crucial in their ability to persevere. Forty-four percent of the respondents stated faculty support was a very important factor to persistence, and only 6% said faculty support was not important.

Factor Five: Relevant subject matter

Yardi and Bruckman (2007) asked computer-science graduate students why the number of computer-science majors seemed to be decreasing. The graduate students tended to agree that the failure to see real-world relevance in this discipline deters many (both male and female) from entering and continuing their experience in computer science. DeClue (2009) noted Carnegie-Mellon's success in increasing female enrollment and suggested that it might be attributed to the computer-science department's emphasis in showing the relevancy of computer science by providing a meaningful context for each computer-science course. The data showed that 42% viewed subject matter relevance as a very important factor to persistence, while 5% rated it as non-essential.

Factor Six: Having female role models

Kahle and Schmidt (2004) lend support that role modeling helps women to maintain a strong interest in computing, resulting in increased persistence. Black et al. (2011) distributed inspiring stories of women in computing to secondary schools, and teacher feedback was exceptionally positive in the belief that the booklet would help recruit and retain female students in computing. The role model factor was rated as the lowest (13% said it was very important) in terms of its importance to persistence. Exactly one-third viewed having a female role model was not important.

Factor Seven: Receiving encouragement

Encouraging and caring advice from faculty and advisors was crucial in helping women avoid feelings of being lost and drowning in the major, which enhanced the ability to endure (Margolis and Fisher, 2002; Cohoon et al., 2008). The encouragement factor was given a very important rating by 41% of the respondents; 5% perceived this factor as not vital.

Factor Eight: Seeing a purpose in computing beyond simply obtaining the degree

Providing a purpose behind the learning is a key to increasing female representation in computing (DeClue, 2009). Connecting computing with a meaningful purpose, such as enhancing medical research, was a more significant reason for being in computer science for women as compared to men (Margolis and Fisher, 2002). Seeing a more noble purpose in computing was viewed as a very important retention factor by 47% of the responders. The non-importance of this factor was reported by 9%.

Factor Nine: Desiring to show women can succeed in the field

Dee, et al., (2009) found that some persisted so they could inspire and teach other women who desire to study computer science. They also found that comments insinuating females cannot succeed in this field served as motivation to remain. This factor, though, was one of the few that had more believing it to be non-important (28%) as opposed to very important (20%).

Factor Ten: An ability to manage the stresses and demands of the major

The ability to cope with the daily challenges, strains, and stresses of a computer-science major had an effect on a student's intention to continue in it (Lewis et al., 2008). As one's ability to cope increases, so does academic achievement (Mayer et al., 2004), which is directly related to a person's persistence in a computer-science program (Katz, et al., 2006). The stress management factor was rated the third highest factor (48%) related to persevering and finishing. A low percentage (3%) viewed it as being inconsequential in helping one to persist.

Factor Eleven: A strong work ethic

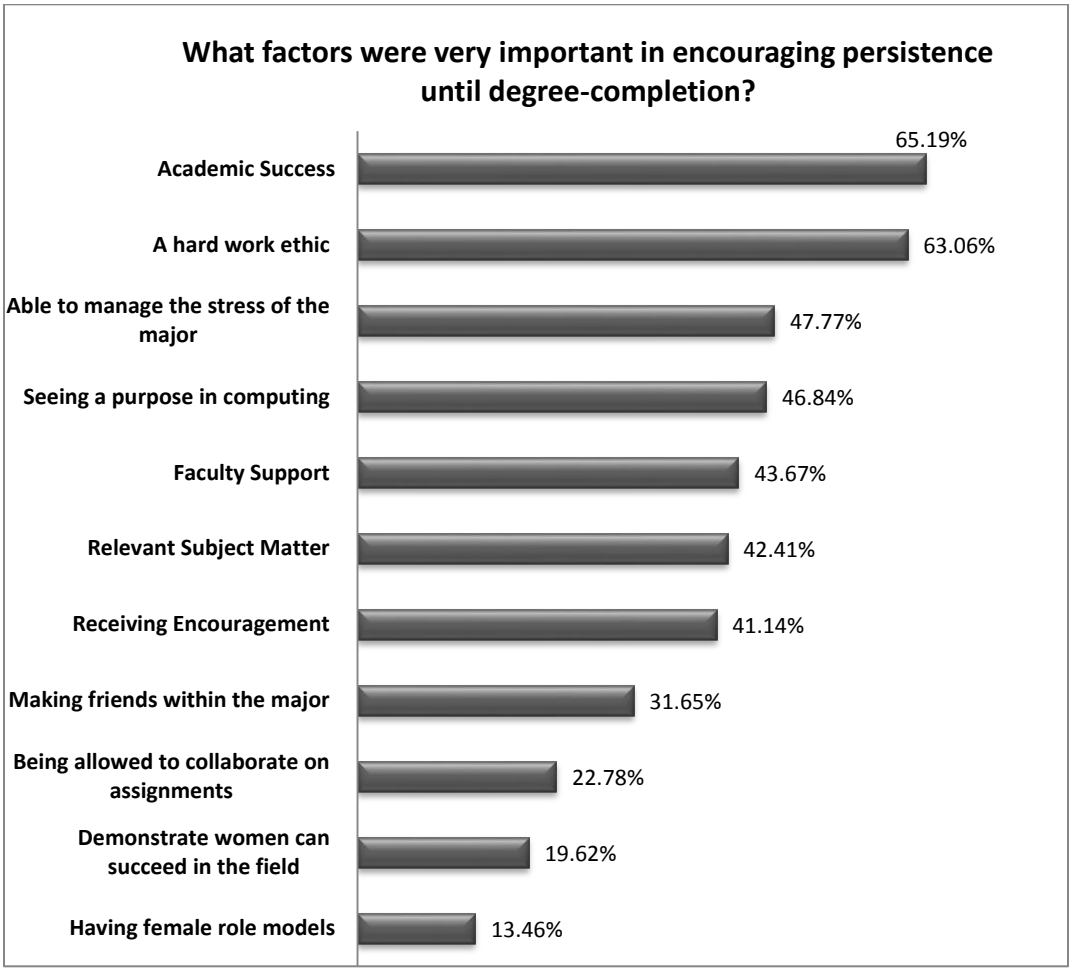
Murphy and Thomas (2008) suggest that within computer-science education, the fixed-versus-growth mindset influences retention. Those with a growth mindset believe that intelligence grows through effort and hard work which can, in turn, lead to successful achievement. Teague (2002) found that problem-solving — a key aspect in computing education — is a major reason why some women stay in computing. Problem-solving challenges one's intellect, and only those who have a hard working mentality can witness the intellectual growth provided through the process of problem-solving. The hard work factor was rated the second highest persistence-related factor (63%) while less than one percent (0.64%) viewed a strong work ethic as non-critical.

Summary of Part One and the Eleven Factors

The data showed that the two highest rated factors related to a female's perseverance and completion of a computing degree were academic success and a strong work ethic (Figure 4). The two lowest rated factors were having female role models and

demonstrating that women can succeed in the field of computing. Figure four displays each persistence factor in order of importance from most important to least important. Appendix Z provides a complete percentage breakdown of the eleven factors and their relative importance to each other.

Figure 4: Important factors encouraging persistence leading to degree-completion



Part Two Results: Open-end question

The open-ended question: "*Reflecting back on your undergraduate experience, how were you able to PERSEVERE and FINISH the major?"* was asked immediately after the eleven research-supported persistence factors were rated for importance. With

this open-ended question placed after the respondent rated the research-supported factors, the respondent had the chance to reflect on how she persisted in her computing major until degree-completion and now had the opportunity to put her thoughts into words.

146 participants responded to this question. Each response was examined at least three times, and the factors encouraging perseverance in a computing degree were noted and added to a master list of factors. After textual analysis, 344 total factors were identified and consolidated into 27 unique factors. Table 6 lists the factors according to their frequency of occurrence in the responses.

Each of the 27 factors was placed in one of the following seven categories, which were created to broadly define the reasons a woman persists and finishes a computing degree. Factor placement can be found in Appendix AA

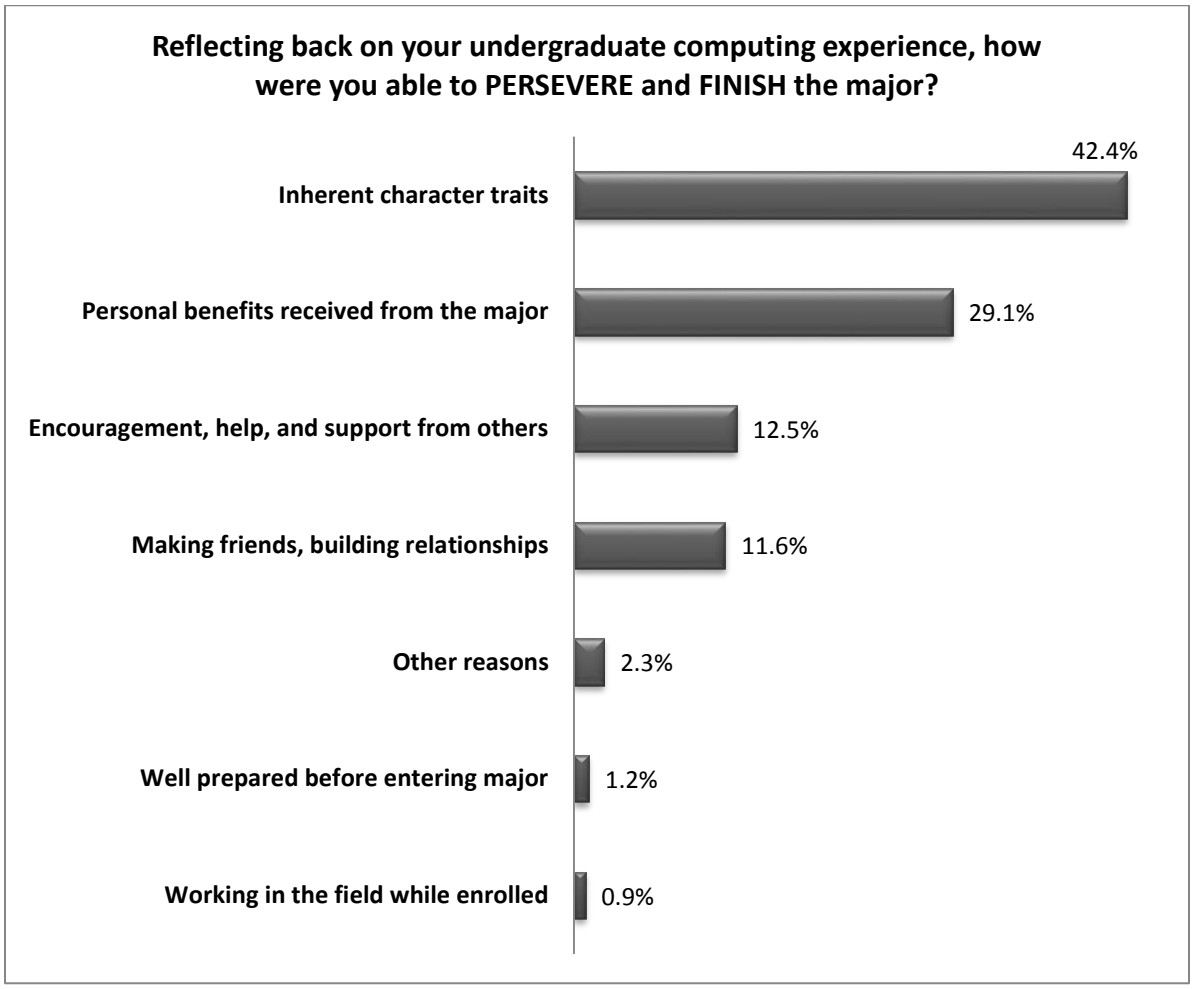
- Inherent character traits
- Personal benefits received from the major
- Encouragement, help, and support from others
- Making friends, building relationships
- Preparedness for the major
- Working in the field while enrolled
- Other reasons

The percentages with a category were calculated by summing the frequencies of the factors belonging to the category and then dividing by the total number of factors found in the responses (344). This percentage allowed the categories to be ranked in order of relative importance to one another as displayed in figure 5.

Table 6: Factors encouraging persistence leading to degree-completion (in the respondents' own words)

Persistence Factor	Frequency
Encouragement, help, support from faculty, friends, family, advisors, role models, women support groups	43
High self-efficacy (confidence in ability to do the work)	29
Determination to finish and succeed	28
Establishing relationships/friendships	27
Loved the work and brought a sense of accomplishment	27
Personally and financially rewarding career awaits	26
Personal pride to finish a goal	25
Subject matter enjoyable, relevant and fit my interests	24
Hard work ethic and effort	23
Responsible (did homework, went to class, self-disciplined, balanced life and work, time management)	18
Major wasn't difficult, stressful or frustrating	17
Committed	16
Collaborative opportunities to learn from others	13
Unafraid to seek help when needed	4
Major was fun	4
Well prepared to enter major	4
Worked in field while enrolled in major; internships	3
Sheer stubbornness (wouldn't quit)	2
Felt like I fit in	2
Too late to change to another major	2
Helped others succeed	1
Didn't want to lose my financial aid	1
Didn't want to let my parents down	1
Good financial support from government	1
Lenient academic rules	1
Didn't want to be a failure	1
Didn't want to waste money and not get a degree	1

Figure 5: Important factors that influence persistence leading to degree-completion (by category)



Summary of Part Two

Analysis of the 27 individual factors enhancing persistence demonstrated how important encouragement was to those responding. Encouragement came from the following sources: faculty, friends, family, advisors, role models, and female support groups. The other factors important to persistence were a high level of self-efficacy, determination, ease in making friends, a love for the work, and an eye to the future, believing a fulfilling and financially rewarding career awaits. In examining the

categories that explain in a broader sense how a woman persists, the data indicates that it is the inherent character traits of a woman such as self-efficacy, determination, and a strong work ethic that have a major impact on a woman staying instead of leaving. Personal benefits received from the major (e.g. a sense of accomplishment, good career prospects), encouragement, and establishing friendships were also primary factors influencing persistence.

Summarizing the Eight Research Questions

The first research question investigated the prevalence of programming experience the participants had prior to enrolling in a computing major. The results indicated that slightly over one-half had a previous course in computing, and it most likely occurred either in senior high-school or college. The one common occurrence these women had with programming was their enjoyment of the activity. One-hundred percent of the students who had previous programming experience reported that they had some degree of enjoyment with programming, with three-fourths indicating their enjoyment level was either high or very high. There were many respondents (43%) who had no prior programming course before declaring a computing major, which would indicate that programming is not a necessary pre-requisite skill in order to pursue or complete a degree in computing. However, those who did take programming enjoyed it. Finally, a love for programming was found to be the third highest factor leading a woman to pursue computing when the participants were asked to state in their own words why they pursued a degree in a computer-related field.

Another common trait found among the participants was their high level of math skill and enjoyment. Upon entering a computing major, it was found that three-fourths of those surveyed had a math skill level of pre-calculus or above, with the majority (59%) stating they had a calculus course or above. Also, enjoyment toward math was discovered to be a prevalent (77%) attitude.

Becoming interested or fascinated with the computer occurred either early (kindergarten thru 5th grade), high-school (10^{th} – 12^{th} grade), or college. However, for more than half of the respondents (52%), this interest or fascination did not translate into a desire to pursue a computing education until college. Less than a third indicated that while in high school they considered the possibility of a computing major in college.

An interesting finding was the degree to which the respondents understood what a computing education entailed. 57% agreed they had some degree of understanding what they would be learning, but 43% disagreed. Many women in this study decided to enter the field (and were successful) despite having a general unawareness of what computing would involve.

Another common trait found among the participants was their level of self-efficacy prior to enrolling in computing study. More than three-fourths were confident in their ability to excel in a computing major, which was interesting when considering that some of these confident individuals were beginning an unfamiliar field of study.

The participants were presented with nine, either extrinsic or intrinsic, factors that research had found influenced a woman toward computing study. The top two factors, one extrinsic and one intrinsic, were excellent employment opportunities in the future,

and the interesting nature of the computing field. The two lowest ranked factors were challenging the perception that only men can succeed in this field, and the development of skills that would one day help society. When asked to respond in their own words why they (the respondents) pursued computing, the factors of future employment opportunities and financial security, programming, high self-efficacy, and the interesting nature of the field were the most frequently cited.

In regard to factors affecting their persistence in the major, the participants were asked the degree of difficulty they experienced from an academic, social, and cultural perspective. The academic side of computing was found to cause the most difficulty in completing the major. The social and cultural aspects of computing caused slight or no difficulty for over 75% of the respondents.

Finally, eleven factors deemed to aid female persistence in a computer major were presented, and the participants rated their degree of importance. The two most important contributors to a woman staying and finishing her degree were experiencing academic success and a hard work ethic. The least important factor was the presence of female role models. The respondents were also asked to state in their own words how they were able to persevere and finish the major. The top factors were found to be encouragement from others, high self-efficacy (continuing to believe they could do the work), determination, making friends, the work bringing a sense of accomplishment, and the potential for a personally and financially rewarding career.

Chapter 5

Conclusions, Implications, Recommendations and Summary

Conclusions

Despite previous and ongoing research efforts, specialized programs, support groups and other attempts to bring more women into computing academia, the field continues to lack a strong female presence that would bring the gender diversity needed. This study attempted to learn from female computing graduates the factors that were most crucial to their enrollment and continual persistence until a degree was obtained. Based on the data analysis and findings in Chapter Four, the following conclusions were reached.

One: Enjoyment in initial programming courses is important to direct a woman toward computing.

Whether or not a woman has had a programming course in her background before enrolling appears to be irrelevant. In this study, there existed a 57% to 43% split between women who had prior experience with programming and those who did not have experience. Every single woman who had prior programming stated that she had some degree of programming enjoyment. In fact, 96% indicated a medium to very high level of enjoyment. Interviews revealed that females who had the first programming class after enrolling enjoyed programming.

Two: A high level of math skill AND enjoyment can lead a woman to computing and enjoyment of it.

Having had at least a pre-calculus course prior to enrolling was found in three-fourths of the participants. Interestingly, some respondents questioned if most of the advanced math knowledge possessed actually helped their academic achievements in computing. What math actually did do to attract women appeared to be two-fold: a) it produced a belief that being good and confident in math would enable them to be good and confident in computing, and b) it provided the logic skills that are invaluable in being successful in programming. Also, it is important to enjoy math, which was reported by 77% of the women. The following interview quote from a participant would adequately summarize this conclusion:

> Well, once I understood that's what computer programming was all about … solving a problem, in a logical, mathematical or orderly type of analytical way. That's where that relationship to math comes in. It wasn't so much (the knowledge) … sure there were times we used algebra, heck, everybody used algebra every day. Calculus, not so much. Did I need it for computer science? No! However, being good at one, I believe certainly would indicate you might be good at the other. Especially if you enjoyed it. If you were good at it (math) but didn't like it you probably wouldn't care for computer science a whole lot.

Three: A majority of women do not decide to pursue computing study until college.

Not making the decision to enter a computer-related degree program until college was the case for over half of the respondents. It is the case, anecdotally speaking, that many students are undecided about what field to pursue when entering college. However, this conclusion also highlights the fact that women, and probably men as well, are not learning much about the computing field prior to college and therefore are

incapable of making a decision earlier about computing as a potential college major. Tim Berners-Lee, who is credited with inventing the World Wide Web, bemoans the fact that most secondary schools are teaching primarily computer applications and calls for computer-science education to be added to school curriculums (VG24/7, 2013). If computer-science courses were more prevalent in secondary schools, it is possible that this exposure might attract more women toward a computing education in college.

Four: Before enrolling, it is not crucial that a woman understand the computing field; however, it is important that she possess the confidence she will excel in it.

Over 40% of the women indicated that they had no understanding of what they would be learning when they began a computing major, and apparently this lack of knowledge about the field is not a deterrent. However, 79% reported that they were confident they would succeed in the field. This conclusion highlights the importance of a woman's self-efficacy before enrolling and emphasizes that confidence in one's ability to foresee success in computing trumps the fear of entering an unfamiliar field.

Five: The perception that computing will one day enable a woman to have a promising and financially successful career is critically important to a woman's decision to enter and continue in computing.

Although the interesting and challenging aspects of computing such as programming and logic are important to women, the highest ranked factor for women choosing computing was the perception that this field would lead to a promising and financially satisfying career. Also, the participants indicated that this belief was a key reason for remaining in the major.

Six: The academic nature of computing causes more problems with persisting and finishing than the social and cultural aspects.

Research is replete with evidence suggesting that the "geek" social nature of computing and the predominance of males within it are primary reasons for female underrepresentation in the field. However, once a woman decides to enroll and enters the academic discipline, the results show that these two issues are not a primary cause for quitting the major, but rather it is the academic side of computing causing more difficulty. 60% stated that academics caused moderate to extreme difficulty in completing the major, while 25% indicated that the social and cultural aspects caused significant problems. This study does not want to minimize the fact that social and cultural issues exist and can severely hamper some women's desire to continue in a computing major.

Seven: Possessing noble character traits, such as humility, determination, a hard work ethic, and confidence along with receiving constant encouragement, and establishing relationships, are crucial in enabling a woman to continue and finish.

Completing a computing major is hard work, and it could be argued that earning any college degree is hard work. It was evident from the results that this sample of female computing graduates had a no-quit attitude, a willingness to work, and a steadfast faith that they would earn a degree. Some of these women also had a realistic expectation and a humility to realize that a computing major is not going to be easy, and as a consequence, the hard times did not make them quit. The following portion of an interview powerfully reflects this type of attitude.

> Okay, let me go back. It's not so much that I was confident I could do that (succeed in computing). I was confident I could give it my best shot and very confident that there were good alternatives if it didn't work out. So I went in with guns blazing and had doubts all throughout. Had doubts after the first semester, felt good after the second semester, felt good after the third, but struggled with the fourth. It depended on the classes, the teachers and the material.
>
> **But, you stayed with it. In other words, it appears like you weren't totally stressed out if you had a bad semester.**
>
> Right, the world is not going to end. I have a very positive outlook on life. The sun will come back up. I will survive this, and if it slaps me in the face that I need to do something else, I can, but I never reached that point. And so, I just stuck with it. I also wanted to get out! I wanted to start working and I didn't want to be set back and have an extra year or anything else. I had invested so much into it towards my junior year for example. Golee, … I said, this is hard and it's okay. *I had to accept that it's okay for me not to be good at everything!"*

Receiving encouragement was the highest ranked factor when the respondents were asked to state in their own words how they were able to persist and finish. Also, establishing relationships within their field was a sustaining factor for many because it helped them navigate the highs and lows of the major. One participant put it this way, "Well, they (relationships) are either for celebrating victories or commiserating. Having someone you can relate to can really help."

Strengths and Implications of the Research

The study data came from a sample of female computing graduates which represented several different computer-related majors, different graduating years (over 24 different years), and degrees from institutions spanning 30 different states. The differences within the sample allowed for different perspectives and experiences to be shared, thus leading to more generalizable conclusions about how a woman decides to

pursue computing and to persist within it. The research effort attempted to re-address issues already discussed in the literature in regard to female underrepresentation and in some cases delve into issues with more specificity, for example, determining the level of math expertise held before entering a computing major and when the decision to pursue a computing education was made. Also, new information was revealed about the women who enter computing and successfully finish a degree. Specifically:

- Before enrolling, programming skill was not a necessary pre-requisite for successfully pursuing the major, but a high level of math skill and enjoyment was important in the decision to enroll and have success.
- Lacking an understanding about the nature of computing education did not deter women from pursuing a computing major in college. More important was an inner confidence that success was highly probable even though the field was unfamiliar.
- Once enrolled, academics posed more of a problem to persistence than social or cultural issues.

Weaknesses, Limitations, and Suggestions for Future Research

Due to the difficulty in locating a sample of female computing graduates, 32% of the study participants graduated from a college or university in the state of Arkansas, and 24% received most of their pre-college education from the same. This result was due to the researcher having more contacts in Arkansas, which led to finding more female graduates. These percentages would tend to slant the experiences, perspectives, and

eventual study results toward the women who were raised and received their computing degree from this state.

The research did not segregate between different computing majors. It is possible that the results could have been different for a computer-science major, which is normally housed in either a school of math or engineering, than for a management information systems major, which is usually located in a school of business. The skills and traits of science-oriented students compared with business-oriented students might yield different results. Investigating the different computer-related majors and finding if the results from this study are the same across the board or vary according to major is suggested as a future research topic. This study combined all majors as a single unit because the graduation data indicated that ALL computer-related majors experience a lack of female representation, and therefore the study focused on what computing majors in general have in common in regard to pursuing and completing a degree.

One factor that was found to be unimportant in a woman's decision to pursue computing was the development of skills that could be used to help society. It has been found that women, more than men, look for a higher purpose in computing than simply computing alone. Surprisingly, this factor was the lowest ranked in terms of importance to the enrollment decision. Why the women in this study did not deem this factor important in deciding to pursue computing was not investigated qualitatively and is recommended as another topic for future research. It is possible the statement, as worded on the survey, did not convey the thought the researcher intended for the participant to consider, thus resulting in an unexpected finding.

Recommendations

The following recommendations are made to program administrators, faculty, recruiters and others who have an influence on women considering computing and women already in the major. It is hoped that these ideas will have a positive impact on achieving more female representation in undergraduate computer-related majors.

One: Work on creating an enjoyable initial programming experience using experienced or trained teachers.

Creating an enjoyable, initial programming course experience for females suggests that teachers examine their methodology when teaching introductory programming courses and stay abreast of new ideas and concepts that would engage and challenge women. Bad teaching, especially in introductory courses, can dishearten students, especially women, but good teaching can cause one to remain or consider the major if not already enrolled. Program chairmen and administrators need to be aware of how the introductory sequence of programming is being taught and monitor attrition rates. Also, it appears that beginning courses need to be taught by experienced or trained teachers, not those new to the profession or those teaching the course as a teaching assistant while working on a degree. Consider this interview segment that begins after an unpleasant experience in a first programming course that almost caused one participant to quit.

> **Okay, let me explore this with you. You take your second programming course after this teacher (in the first programming course) made you question what you were doing. What was your experience in that second programming course?**

> It was different, well, it was awesome. It was a PL1 class and it was a huge class. So, there were about 150 students in the class probably. It was one of those auditorium type classes. The teacher was more experienced. I suspect he probably chose teaching as a profession because he enjoyed teaching, not because he was working on a degree. He made the class very interesting. And so things I sort of learned in that first semester started making sense. Now I see what's the value in this, and I understand how these pieces and parts come together and I began comprehending what programming was about. That helped to inspire me to say I like this now that I have a better understanding of what it is.
>
> **If I'm hearing you right, basically it took a good teacher, an experienced teacher in the discipline of programming and in computer science to try to elicit that positive response in you.**
>
> Yes, it took someone who was excited about what he was teaching, which equates to a good teacher anyway. I no longer felt I was in completely over my head. Not to say I didn't feel in over my head several times after that (laughing). But at least in that point in time it all started coming together, and I had at least a better understanding of what I had gotten myself into.

Two: Focus on the math background of a prospect when recruiting

This recommendation is not intended to dissuade recruiters and faculty from pursuing any female who shows interest in a computing degree program. However, it is recommended that those who do recruit be honest and tell prospects that a strong math background and enjoyment of the subject are characteristic of those who finish the degree, and that programming skill is not a necessary pre-requisite in order to begin. In other words, recruiting should focus more on math background than on programming background. For those women who do not possess a strong math background but enjoy the subject, it is recommended that a math course of at least pre-calculus be required.

Three; Encourage, encourage, encourage

When responding to the question "*How were you able to persevere and finish the major?"* the most frequently mentioned factor — by a fairly wide margin over other factors — was encouragement. Administrators and faculty would be wise to consider ways to encourage students often and regularly instead of every once in a while. This action will help all students but especially the women who reside in programs where they are in the minority. Faculty members have the most potential to provide women with the needed encouragement because of their engagement with them in the classroom.

Four: Diligently promote the career opportunities in computing

This recommendation serves to help increase enrollment of women but also to aid in their persistence. The top two factors mentioned by women when answering the question "*Why did you ultimately decide to pursue computing study?"* were career opportunities and financial security. It is recommended that computing departments keep up-to-date documentation on the various career paths majors can take after graduating and associated salary prospects for each career path. On the front end, women are particularly concerned about where a computing major will lead them. Providing evidence that the major can prepare them for a satisfying and financially rewarding career can influence their enrollment decision. Once in the program, future careers and financial security become prime factors in helping women to continue and finish.

Five: Provide opportunities for the building of relationships

Establishing relationships was a high-ranking factor in regard to persistence and completion. Computing departments are encouraged to have more activities where people can get together and know each other outside the classroom experience. It is also suggested that collaborative exercises be incorporated within classes where relationships might be forged.

Summary

The percentage of women graduates in undergraduate computer-related degree programs in the United States has steadily decreased over the past three decades. A specific computer-related program, computer science, provides startling proof of the continual percentage decline in female graduation rates. In 1982, 35% of computer-science degrees went to women (Grant & Snyder, 1985-86). Approximately thirty years later, in the school year 2010-2011, Zweben (2012) reports that women earned only 11.7% of computer-science degrees. These figures show that between 1982 and 2011, there has been a 67% decline. Research has offered several reasons for the decline, and these reasons include a lack of computing courses in most high schools, which prevents females from determining if computing would be of interest to them (Buzzetto-More, Ukoha, & Rustagi, 2010), a perception that the field is considered to be gender-specific toward males (Margolis & Fisher, 2002; Papastergiou, 2008), and the belief that the computing field is anti-social (Ali, 2009).

The two primary concerns affecting female participation in undergraduate computing programs are a declining enrollment (Carlson, 2006; Lenox et al., 2008) and attrition rates that are higher than men's (Cohoon and Aspray, 2006). Solutions to these two issues will benefit the U.S. workforce because gender-balanced graduating classes mean a uniform proportion of competent, diverse talent, which is a necessity for the technology industry (Cohoon & Aspray, 2006; Ramsey & McCorduck, 2005; Simard, 2007).

The primary goal of this study was to acquire a better understanding of the factors leading a woman to pursue a computing education and to remain until a degree is earned. To find these factors, female computing graduates were asked to provide their insights. It is believed that the knowledge gained from these successful women can help devise better recruiting strategies by knowing what the attractions are for women toward computing. Also, administrators and faculty in computer-related majors will be better aware of what helps a woman to continue in a computing major, and thereby be more effective in encouraging persistence until degree-attainment.

A sequential explanatory methodology, which is also called a QUAN-qual approach, was used to implement the research. Data collection and analysis was performed in two phases. Phase I (the quantitative phase) used an online survey called the *Female Computing Graduate Survey* to gather data from 160 female computing graduates. After analyzing the data, core factors directing a woman toward computing and aiding in her persistence within it were discovered. The second phase (the qualitative phase) involved conducting interviews with a few

of the participants who were willing to discuss their enrollment and persistence in depth. The interview questions were not developed until after phase I data analysis. Six participants were purposefully selected based on their survey responses and their ability to articulate the findings from Phase I.

The first research question investigated the prevalence of programming experience prior to enrolling in a computing major. The results showed that over one-half had a previous course in computing and occurred either in senior high-school or college. The one common occurrence these women had with programming was their enjoyment of the activity. All of the women who had previous programming experience reported that they had some degree of enjoyment with programming, with three-fourths indicating their enjoyment level was either high or very high. There were many respondents (43%) who had no prior programming course before declaring a computing major, which would indicate that programming is not a necessary pre-requisite skill in order to succeed in a computing major.

Another common trait found among the participants was their high level of math skill and enjoyment. Upon entering a computing major, it was found that three-fourths of those surveyed had a math skill level of pre-calculus or above. Also, enjoyment toward math was discovered to be a prevalent (77%) attitude. Interviews revealed that math skill and enjoyment was a factor in deciding to enroll in computing study. Math also proved to be an aid in persistence in the major due to the logic skills gained from math and the confidence attained by having a strong math background.

Becoming interested or fascinated with the computer occurred either early (kindergarten thru 5th grade), in high-school (10^{th} – 12^{th} grade), or in college. However, for more than half of the respondents (52%), this interest or fascination did not translate into a desire to pursue a computing education until college, not before. Less than a third indicated that they considered the future possibility of studying computing in high school.

An interesting finding was the degree to which the respondents understood what a computing education entailed. 57% agreed they had some degree of understanding what they would be learning, but 43% disagreed. Many women in this study decided to enter the field (and were successful) despite initially having a general unawareness of what computing would involve.

Another common trait found among the participants was their level of self-efficacy prior to enrolling in computing study. More than three-fourths were confident in their ability to excel in a computing major. This finding was surprising considering that some of these confident individuals were beginning an unfamiliar field of study.

The participants were presented with nine, either extrinsic or intrinsic, factors that had research supporting their influence in directing a woman toward computing study. The top two factors, one extrinsic and one intrinsic, were the prospect of excellent employment opportunities after graduation and the interesting nature of the computing field. When asked to respond in their own words why they (the respondents) pursued computing, the factors of future employment opportunities and financial security, programming, high self-efficacy, and the interesting nature of the field were the most frequently cited.

In regard to factors affecting their persistence in the major, the participants were asked the degree of difficulty they experienced from an academic, social, and cultural perspective. The academic side of computing was found to cause the most difficulty in completing the major. The social and cultural aspects of computing caused only slight or no difficulty for over 75% of the respondents.

Finally, eleven factors deemed to aid persistence in a computer major were presented, and the participants rated their degree of importance. The two most important contributors to a woman staying and finishing her degree were experiencing academic success and having a strong work ethic. The respondents were also asked to state in their own words how they were able to persevere and finish the major. The top factors were found to be encouragement from others, high self-efficacy (continuing to believe they could do the work), determination, an ability to make friends, a love for the work because it brought a sense of accomplishment, and anticipation of a personally and financially rewarding career.

In bringing the study to a close, the following seven conclusions were reached:

1) Enjoyment in initial programming courses is necessary in order to direct a woman toward computing.

2) A high level of math skill AND enjoyment can lead a woman to computing and enjoyment of it.

3) A majority of women make the decision to pursue a computing education in college, not before.

4) Before enrolling, it is not crucial that a woman understand the computing field: however, it is important that she possess the confidence she will excel in the field.

5) The perception that computing will one day enable a woman to have a promising and financially successful career is critically important to a woman's decision to enter and continue in computing.

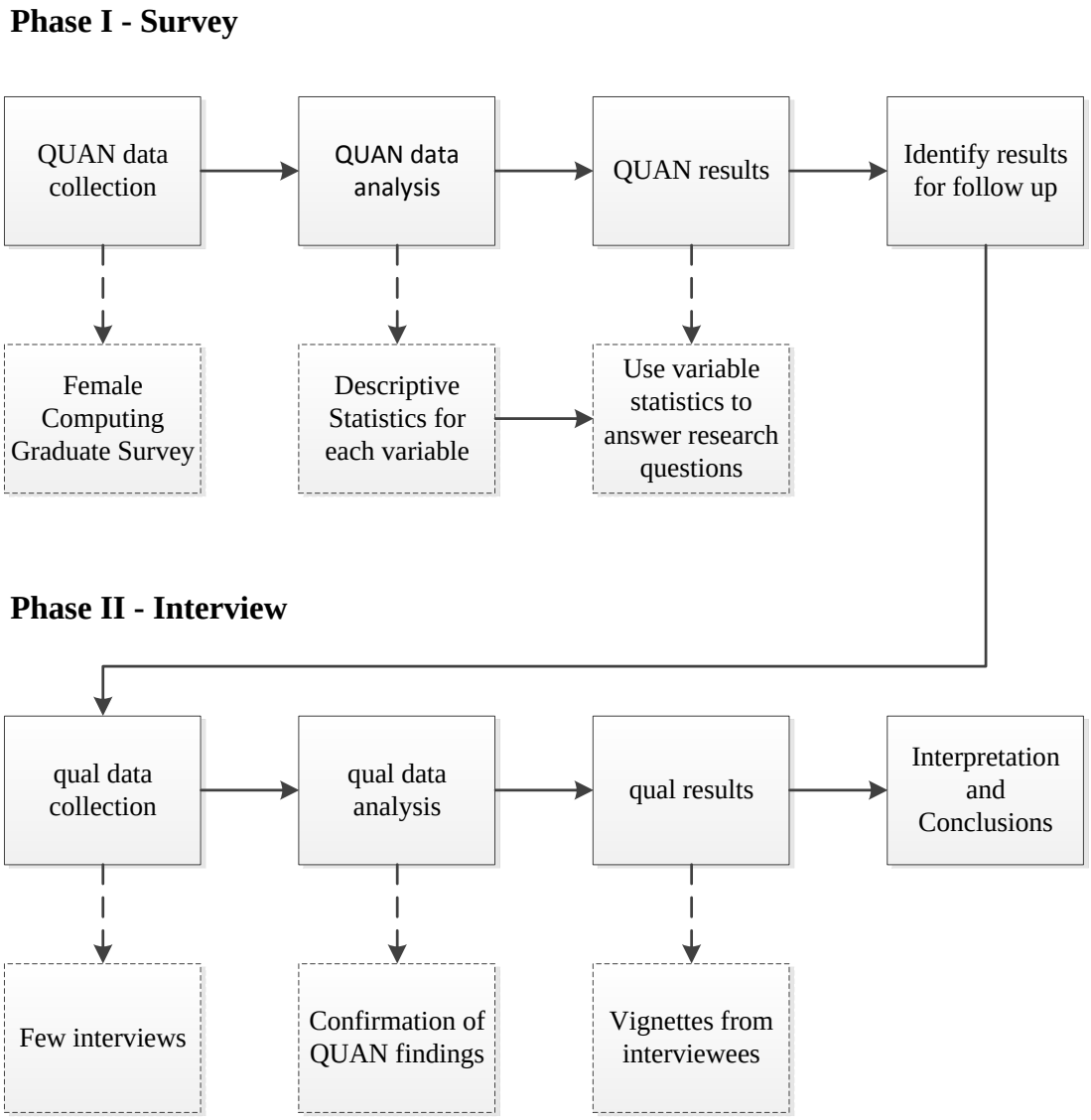
6) The academic nature of computing causes more problems with persisting and finishing than the social and cultural aspects.

7) Possessing noble traits, such as humility, determination, a strong work ethic, and confidence, along with receiving constant encouragement, and establishing friendships are essential in enabling a woman to continue and finish.

Appendix A

Sequential Explanatory - Mixed Method Design

(QUAN -> qual study)



Appendix B

Female Computing Graduate Survey (FCGS)

FCGS

Female Computing Graduate Survey

You are invited to participate in a dissertation research study focusing on female underrepresentation in undergraduate computing degree programs. The objective of this research is to attempt to understand better how a woman determines to pursue a computing education and perseveres in it until obtaining a degree. The survey is being sent to women who are believed to have completed an undergraduate computer-related degree.

The risk associated with this study is minimal, that is, not greater than risks ordinarily encountered in daily life. However, there does exist the risk of possible loss of confidentiality if you are willing to participate in a later interview. You will be asked to provide name/contact information which can be linked to your survey responses. Your name/contact information and data will be stored securely on the researcher's laptop computer and will be backed up on files within a server that only the researcher can access. This information will be stored for three years from the conclusion of the study and then deleted.

There are no costs for participating in this study. The information collected may not benefit you directly, but what I learn from this study could provide inspiration and encouragement to women who are capable of pursuing a computing education. Additionally, results from the study may provide additional insights needed to more effectively recruit women to computing academia. Professors and administrators in academic computing fields will also benefit from knowing what encourages women to stay in the field rather than leave.

All information obtained in this study is strictly confidential unless disclosure is required by law. Also, my dissertation chairman and IRB (institutional review board) may review research records. Any information that would identify you will not be given in the final dissertation report.

Your participation in this study is voluntary. By beginning the survey, you acknowledge that you have read this information and agree to participate in this study, with the knowledge that you are free to withdraw your participation at any time by simply closing the browser window.

If you have any questions or concerns about completing the survey or about your involvement in this study, you may contact me at ragsdale@harding.edu, or you may call me directly at (501)281-0367.

---

1) Did you receive an undergraduate degree in computing?

- Yes
- No

IMPORTANT: If you answered "no" to this question, you do not need to complete the survey. The survey is designed for those who completed an undergraduate computing degree. Please scroll to the bottom of the survey and

click submit. You may then exit this browser window. Thank you.

---

2) Your undergraduate computing degree was in:

- Computer Science
- Computer Engineering
- Information Systems
- Information Technology
- Management Information Systems
- Software Development/Engineering
- Other

3) What year did you receive your undergraduate computing degree?

2012

4) Where is your degree-granting institution located?

Alabama

5) Where did you receive the majority of your pre-college education (elementary school, middle school, junior high, high school)?

Alabama

6) Did you take any programming course(s) (e.g. C++, Java, Scratch, Alice, etc) before enrolling in a computing major?

- Yes
- No

6a) If you answered "yes" to question #6, when did you take your *first* programming course?

- Before Middle School
- Middle School (6th-7th)
- Junior High (8th-9th)
- High School (10th-12th)
- College

6b) If you answered "yes" to question #6, what was your level of enjoyment in your programming course(s)?

- Very High
- High
- Medium
- Low
- Very Low

7) What was the *highest* level math course you took before enrolling in a computing major?

Algebra I or lower

8) How would you respond to the statement: *"I enjoyed the subject of math in my pre-college years."*

- Strongly Agree
- Agree
- Neither Agree or Disagree
- Disagree
- Strongly Disagree

9) When did you first experience an *interest* or *fascination* with the computer?

- Pre-school
- Elementary School (K - 5th)
- Middle School (6th - 7th)
- Junior High (8th - 9th)
- High School (10th - 12th)
- College

10) When did you first consider you might want to *pursue* a computing education?

- Pre-school
- Elementary School (K - 5th)
- Middle School (6th - 7th)
- Junior High (8th - 9th)
- High School (10th - 12th)
- College

11) How would you respond to the statement: *"Before enrolling in a computing major, I had an accurate understanding of what I would be learning in the major."*

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

12) How would you respond to the statement, *"Before enrolling in a computing major, I was confident in my ability to excel in the major."*

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree

13) When you made the decision to *PURSUE* a computing education, indicate the relative importance each of the following had in your decision-making process.

	Very Important	Somewhat Important	Somewhat Unimportant	Not Important

My enjoyment of computers and technology

The availability of excellent employment opportunities after graduating with a computing degree.

The field of computing seemed to be interesting

Believing I was going to be challenged intellectually

I would develop skills that would one-day help develop positive solutions for society

The work in the major would be personally rewarding

The encouragement I received from significant others (parents, friends, teachers)

The desire to challenge the perception that only men can succeed in this field

A future in computing would be financially rewarding.

14) Why did you ultimately decide to *PURSUE* a computing education?

15) From an *ACADEMIC* standpoint, how difficult was it to complete the major? (In other words, how hard was the major academically (taking tests, assignments, etc.)?)

- Very difficult
- Moderately difficult
- Slightly difficult
- Not difficult

16) From a *SOCIAL* standpoint, how difficult was it to complete the major? (In other words, how difficult was it to work and interact with your computing peers?)

- Very difficult
- Moderately difficult
- Slightly difficult
- Not difficult

17) From a *CULTURAL* standpoint, how difficult was it to complete the major? (In other words, did being engaged in a field commonly perceived as a male domain make perseverance difficult?)

- **Very difficult**
- **Moderately difficult**
- **Slightly difficult**
- **Not difficult**

18) Please indicate the relative importance each of the following had in helping you *PERSEVERE* and *FINISH* the computing major.

	Very Important	Somewhat Important	Somewhat Unimportant	Not Important
Making friends within the major				
Being allowed to work with others on assignments				
Academic success				
Faculty support				
Relevant subject matter				
Having female role model(s)				
Receiving encouragement				

Seeing a purpose in computing beyond simply obtaining the degree

Desiring to show that women can succeed in this field

An ability to manage the stresses and demands of the major

A hard work ethic

19) Reflecting back on your undergraduate computing experience, how were you able to *PERSEVERE* and *FINISH* the major?

20) Would you be willing to be interviewed to explore further how you came to enroll in a computing major, and your perseverance that led to attainment of a computing degree?

Yes

No

21) If you answered yes to the previous interview question, would you please supply your name and the best way to contact you.

This concludes the *Female Compting Graduate Survey* (FCGS). Please review your responses for accuracy and then click the *submit* button.

Submit

Appendix C

IRB Approval – Harding University

HARDING UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Status of Request for Exemption from IRB Review

(For Board Use Only)

Date: May 15, 2012

Proposal Number: 2012 - 056

Title of Project: Pursing and Completing an Undergraduate Computer Science Degree from a Female Prespective: A Qualitative and Quantitative Analysis

Name and Contact information for the Principal Investigator: Scott Ragsdale; ragsdale@harding.edu

■ Research exempted from IRB review.

☐ Research requires IRB review.

☐ More information is needed before a determination can be made. (See attachment.)

I have reviewed the proposal referenced above and have rendered the decision noted above. This study has been found to fall under the following exemption(s):

1 ☐ 2 ■ 3 ☐ 4 ☐ 5 ☐ 6 ☐

In the event that, after this exemption is granted, this research proposal is changed, it may require a review by the full IRB. In such case, a ***Request for Amendment to Approved Research*** form must be completed and submitted.

This exemption is granted for one year from the date of this letter. Renewals will need to be reviewed and granted before expiration.

The IRB reserves the right to observe, review and evaluate this study and its procedures during the course of the study.

Rebecca O. Weaver

Chair
Harding University Institutional Review Board

Appendix D

IRB Approval – Nova Southeastern University

NOVA SOUTHEASTERN UNIVERSITY

MEMORANDUM

To: Scott Ragsdale, M.S.E.
Graduate School of Computer and Information Sciences

From: David Thomas, M.D., JD. JD for DT
Vice-Chair, Institutional Review Board

Date: July 30, 2012

Re: *Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Analysis*
Research Protocol No. 06201217Exp.

I have reviewed the revisions to the above-referenced research protocol by an expedited procedure. On behalf of the Institutional Review Board of Nova Southeastern University, *Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Analysis* is approved in keeping with expedited review categories #6 and #7. Your study is approved on **July 30, 2012** and is approved until **July 29, 2013**. You are required to submit for continuing review by **June 29, 2013**. As principal investigator, you must adhere to the following requirements:

1) CONSENT: You must use the stamped (dated consent forms) attached when consenting subjects. The consent forms must indicate the approval and its date. The forms must be administered in such a manner that they are clearly understood by the subjects. The subjects must be given a copy of the signed consent document, and a copy must be placed with the subjects' confidential chart/file.

2) ADVERSE EVENTS/UNANTICIPATED PROBLEMS: The principal investigator is required to notify the IRB chair of any adverse reactions that may develop as a result of this study. Approval may be withdrawn if the problem is serious.

3) AMENDMENTS: Any changes in the study (e.g., procedures, consent forms, investigators, etc.) must be approved by the IRB prior to implementation.

4) CONTINUING REVIEWS: A continuing review (progress report) must be submitted by the continuing review date noted above. Please see the IRB web site for continuing review information.

5) FINAL REPORT: You are required to notify the IRB Office within 30 days of the conclusion of the research that the study has ended via the IRB Closing Report form.

The NSU IRB is in compliance with the requirements for the protection of human subjects prescribed in Part 46 of Title 45 of the Code of Federal Regulations (45 CFR 46) revised June 18, 1991.

Cc: Dr. Ling Wang
Dr. Steven Terrell
Ms. Jennifer Dillon

Institutional Review Board
3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-5369 • Fax: (954) 262-3977 • Email: irb@nsu.nova.edu • Web site: www.nova.edu/irb

Appendix E

IRB Approval (Amended) – Nova Southeastern University

NOVA SOUTHEASTERN UNIVERSITY

MEMORANDUM

To: Scott Ragsdale, M.S.E.
Graduate School of Computer and Information Sciences

From: David Thomas, M.D., J.D. DT For DT
Chair, Institutional Review Board

Date: February 22, 2013

Re: *Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Analysis*
Research Protocol No. 06201217Exp.

I have reviewed the amendment to the above-referenced research protocol by an expedited procedure. On behalf of the Institutional Review Board of Nova Southeastern University, the following amendment to *Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Analysis* is approved:

- Amendment to include seven interview questions. Between 6 to 12 interviews will be needed to provide the confirmation desired

Please note that this does not affect the continuing review date for this protocol.

Cc: Dr. Ling Wang
Dr. Steven Terrell
Ms. Jennifer Dillon

Institutional Review Board
3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-5369 • Fax: (954) 262-3977 • Email: irb@nsu.nova.edu • Web site: www.nova.edu/irb

Appendix F

Approved Consent Form for an Interview

NOVA SOUTHEASTERN UNIVERSITY
Graduate School of Computer and Information Sciences

NSU

NOVA Institutional Review Board
Approval Date: JUL 30 2012
Continuing Review Date: JUL 29 2013

Consent Form for Participation in the Research Study Entitled
Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Approach

Funding Source: None.

IRB protocol # 06201217Exp.

Principal investigator
Scott Ragsdale, M.S.E.
101 River Oaks Court
Searcy, AR. 72143
(501) 281-0367

Co-investigator
Steven Terrell, Ph.D.
3301 College Avenue
Fort Lauderdale, FL 33314
(954) 262-2084

For questions/concerns about your research rights, contact:
Human Research Oversight Board (Institutional Review Board or IRB)
Nova Southeastern University
(954) 262-5369/Toll Free: 866-499-0790
IRB@nsu.nova.edu

Site Information
Nova Southeastern University
Graduate School of Computer and Information Sciences
3301 College Avenue
Fort Lauderdale, FL 33314

What is the study about?
You are invited to participate in a research study. The goal of this study is to understand better how a woman determines to pursue an undergraduate computing degree and perseveres in it until degree attainment.

Why are you asking me?
We are inviting you to participate because you indicated on the *Female Computing Graduate Survey* that you received a computer-related degree and that you were willing to participate in an interview. There will be between 6 and 12 women interviewed.

What will I be doing if I agree to be in the study?
You have already completed a survey. You will now be interviewed by the researcher, Mr. Ragsdale. Mr. Ragsdale will ask you questions that will explore in greater depth your decision to pursue an undergraduate computing degree and how you were able to persevere until you attained the computing degree. The interview should last between 15 and 30 minutes. Please know that you may terminate the interview at any time.

Is there any audio or video recording?
This research project will include audio recording of the interview. This audio recording will be available to be heard by the researcher, Mr. Ragsdale, personnel from the IRB, and the dissertation chair, Dr. Terrell. The recording will be transcribed by Mr. Ragsdale. Mr. Ragsdale will use earphones while transcribing the interviews to guard your privacy. The recording will be kept securely in Mr. Ragsdale's office in a locked box. A copy of the recording will also be kept on Ragsdale's laptop computer in a secure file folder and an additional backup will be maintained on a secure server at Harding University. Mr Ragsdale will be the only person able to access the recording on the laptop and the server. The recording will be kept for 36 months (3 years) from the end of the study and will be destroyed after that time by shattering the medium on which it is stored and deleting the recordings on the laptop computer. The transcripts will be destroyed by shredding. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will try to limit access to it as described in this paragraph.

What are the dangers to me?
Risks to you are minimal, meaning they are not thought to be greater than other risks you experience every day. Being recorded means that confidentiality cannot be promised. If you have questions about the research, or your research rights contact Mr. Ragsdale at (501) 281-0367. You may also contact the IRB at the numbers indicated above with questions about your research rights.

Are there any benefits to me for taking part in this research study?
There are no benefits to you for participating.

Will I get paid for being in the study? Will it cost me anything?
There are no costs to you or payments made for participating in this study.

How will you keep my information private?
The procedure used to safely secure the audio recording has been described above. The transcription and consent form will be stored in a file folder in the primary researcher's office within a locked box. The recording, transcription, and consent form will be destroyed 36 months after the study ends. All information obtained in this study is strictly confidential unless disclosure is required by law. The IRB, regulatory agencies, or Dr. Terrell may review research records.

What if I do not want to participate or I want to leave the study?
You have the right to leave this study at any time or refuse to participate. If you do decide to leave or you decide not to participate, you will not experience any penalty or loss of services you have a right to receive. If you choose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study and may be used as a part of the research.

NOVA
Institutional Review Board
Approval Date: JUL 30 2012
Continuing Review Date:
JUL 29 2013

Other Considerations:
If the researchers learn anything which might change your mind about being involved, you will be told of this information.

Voluntary Consent by Participant:
By signing below, you indicate that

- this study has been explained to you
- you have read this document or it has been read to you
- your questions about this research study have been answered
- you have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
- you have been told that you may ask Institutional Review Board (IRB) personnel questions about your study rights
- you are entitled to a copy of this form after you have read and signed it
- you voluntarily agree to participate in the study entitled *Pursuing and Completing an Undergraduate Computing Degree from a Female Perspective: A Quantitative and Qualitative Approach*

Participant's Signature: _____ Date: _____

Participant's Name: _____ Date: _____

Signature of Person Obtaining Consent: _____

Date: _____

NOVA
Institutional Review Board
Approval Date: JUL 30 2012
Continuing Review Date: JUL 29 2013

Appendix G

Interview Questions

1) Having an enjoyable experience in a programming course prior to pursuing a computing major appears to be a factor that will lead a woman to study computing at the undergraduate level. In fact, 57% of those surveyed indicated this was the case for them. However, 43% indicated no prior programming course (you were in this group). What was your reason for not taking a programming class prior to enrolling? When you took your first programming course, once in the major, what was your experience?

2) A high level of math skill (pre-calculus or above) was found in 75% of the respondents and 77% indicated a enjoyment of math before enrolling. Math has shown in some studies to direct a woman toward computing. Was this true for you and how so? Also, do you think math skill and enjoyment aided in your persistence and why?

3) Slightly over half of the respondents (52%) did not consider an education in a computing field until college. Why was this true for you?

4) Less than a third (32%) considered pursuing a computing education in high school. Why was this true for you?

5) About 43% of the respondents enrolled in a computing field of study despite not having much understanding in regard to what they would be learning in the major. Why did you decide to enroll even though you had very little, if any, knowledge about what you would be studying and learning?

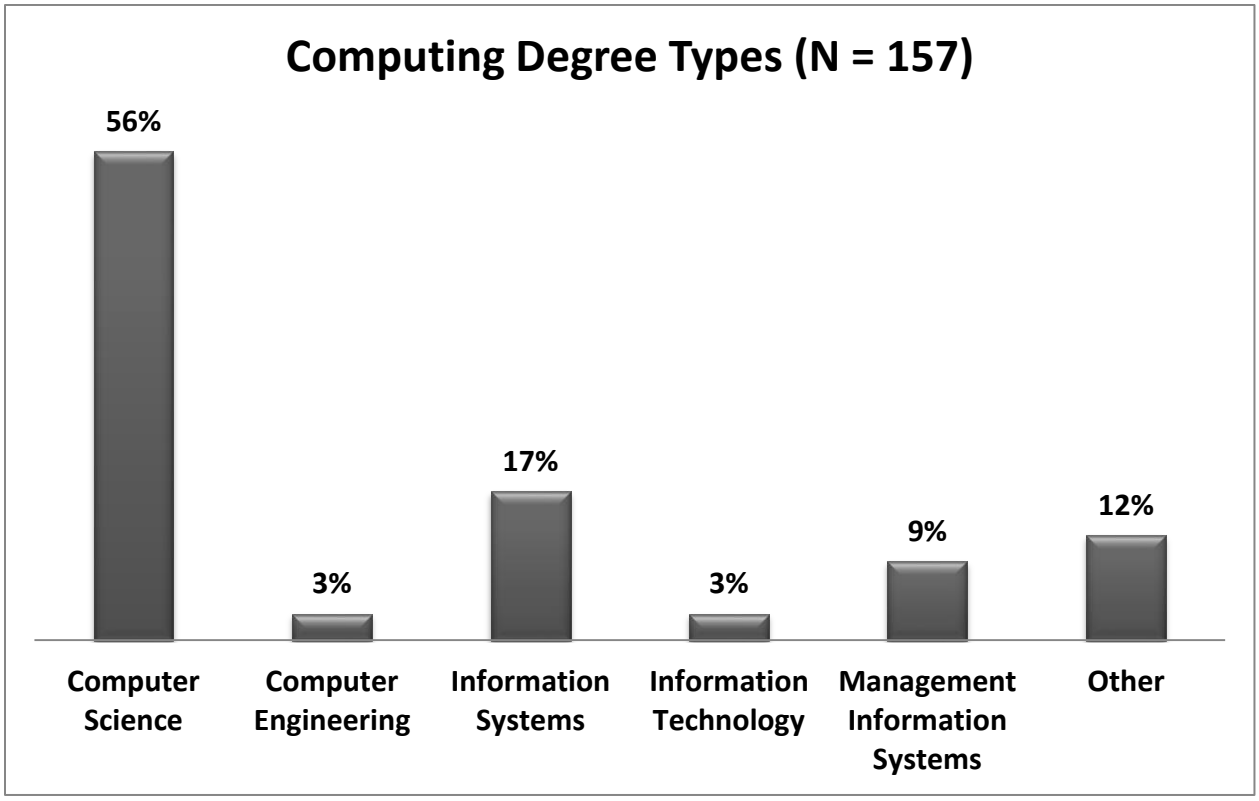
6) Where did you obtain the confidence or faith that you could excel in computing despite having no knowledge of what a computing education entailed?

7) Some research indicates that women will not pursue or continue in computing due to the social atmosphere of computing (geekiness, non-social perception, people pretty much stay to themselves). You indicated that the social atmosphere did not cause you a problem. Please explain.

8) Some research indicates that women will not pursue or continue in computing due to the cultural atmosphere of computing (field more suited for men, male dominated). You indicated that the cultural atmosphere did not cause you a problem. Please explain.

Appendix H

Demographic Information: Types of Computing Degrees Represented



Other computing degree types:

Accounting Information Systems
Biotechnology
Business Data Processing
Cognitive Science with emphasis in Artificial Intelligence
Computer and Informational Sciences
Computer Information Systems
Computer Information Systems and Quantitative Analysis
Computer Science & Cognitive Pyschology
Computer Science and Engineering
Electrical Engineering/Computer Science (2)
Engineering Mathematics
Math/Computer Science (2)
Music/Computer Science
Network Administration
Software Development/Engineering
Web Development

Appendix I

Demographic Information: Year Computing Degree Received

Year degree received	Frequency
2012	11
2011	9
2010	5
2009	11
2008	6
2007	5
2006	4
2005	10
2004	6
2003	4
2002	5
2001	6
2000	11
1999	3
1998	5
1997	3
1996	4
1995	3
1994	5
1993	3
1992	3
1991	5
1990	1
1989	0
1988	3
Before 1988	29
Total	**160**

Appendix J

Demographic Information: States Where Degrees Were Granted

(N = 160)

State	Frequency	State	Frequency
Alabama	5	Michigan	1
Arizona	1	Mississippi	1
Arkansas	51	Missouri	12
California	14	New Jersey	2
Colorado	1	New Mexico	1
Connecticut	1	New York	4
Florida	2	North Carolina	2
Georgia	4	Ohio	1
Illinois	6	Oklahoma	4
Indiana	2	Pennsylvania	12
Kansas	1	Tennessee	3
Louisiana	4	Texas	6
Maine	1	Virginia	2
Maryland	3	Washington	1
Massachusetts	8	Wisconsin	4

Appendix K

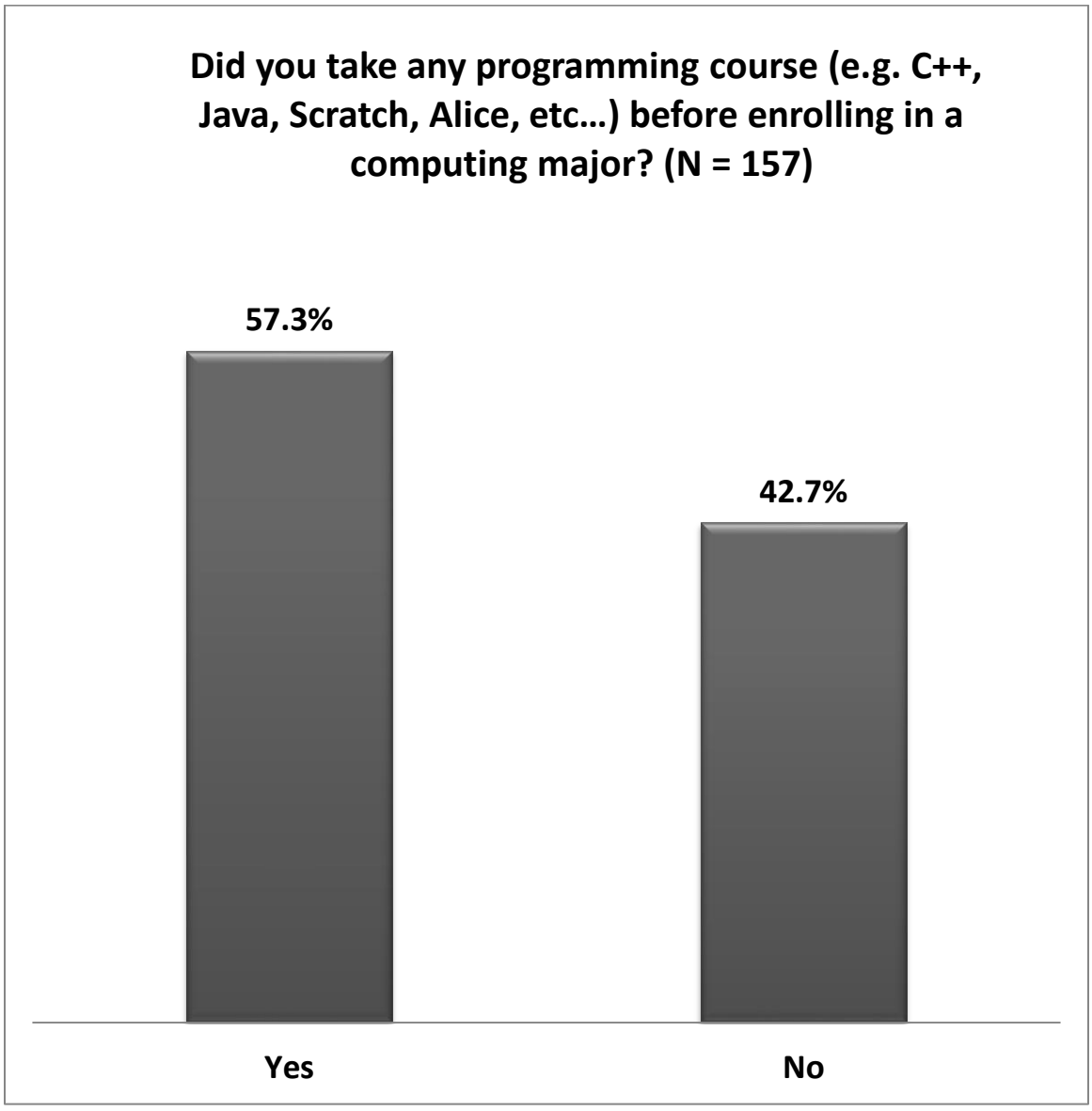
Demographic Information: States Where Majority of Pre-College Education Received

(N=160)

State	Frequency	State	Frequency
Alabama	5	New Jersey	4
Arkansas	39	New Mexico	1
California	13	New York	10
Florida	2	North Carolina	2
Georgia	5	Ohio	3
Illinois	3	Oklahoma	4
Indiana	1	Pennsylvania	7
Iowa	1	Rhode Island	1
Kansas	3	South Carolina	1
Louisiana	5	Tennessee	3
Maine	1	Texas	13
Maryland	5	Vermont	1
Massachusetts	1	Virginia	1
Michigan	5	Washington	2
Mississippi	1	Wisconsin	2
Missouri	9	Outside the U.S.	6

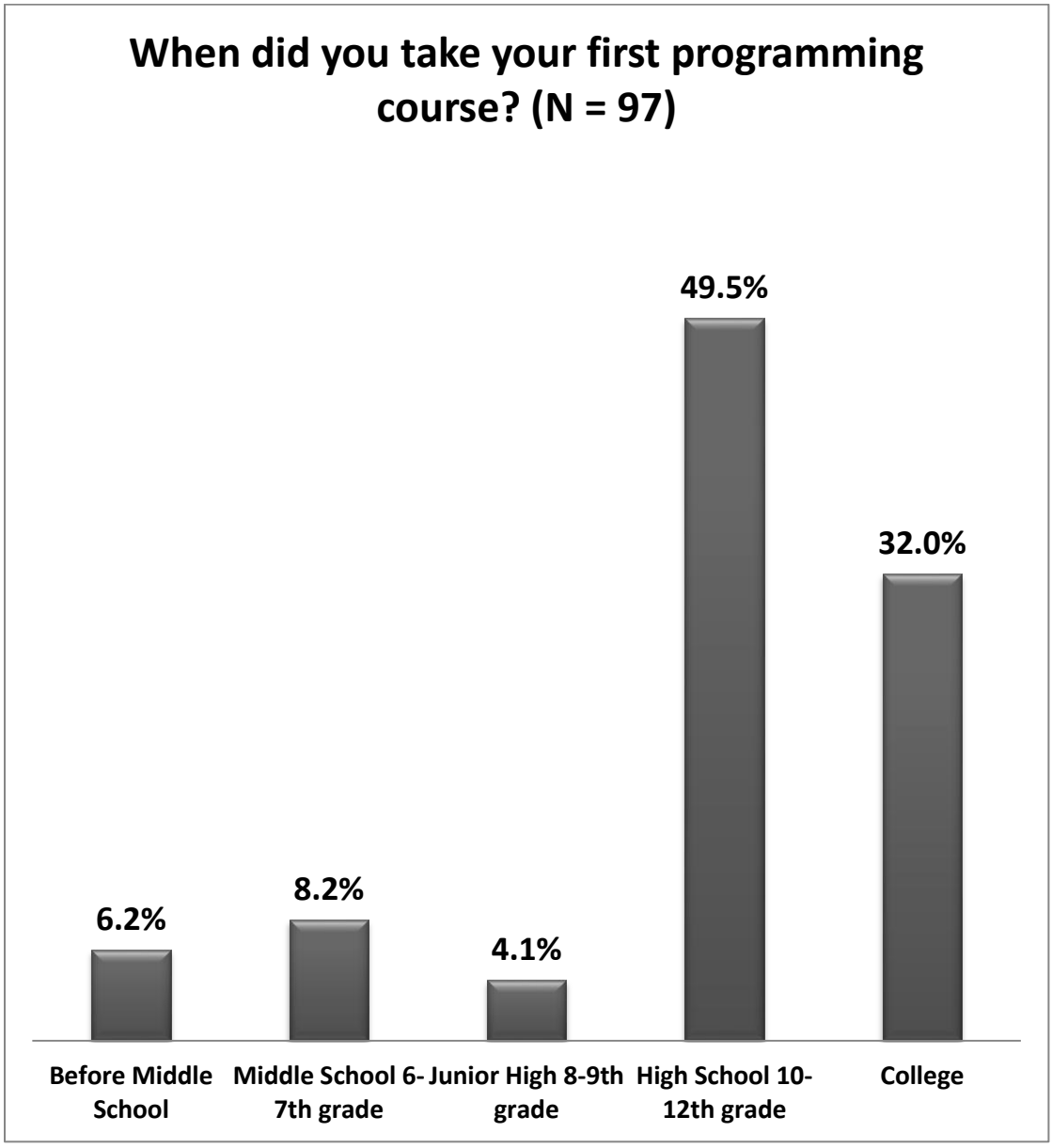
Appendix L

Research Question One: Programming Course Prior to Enrolling



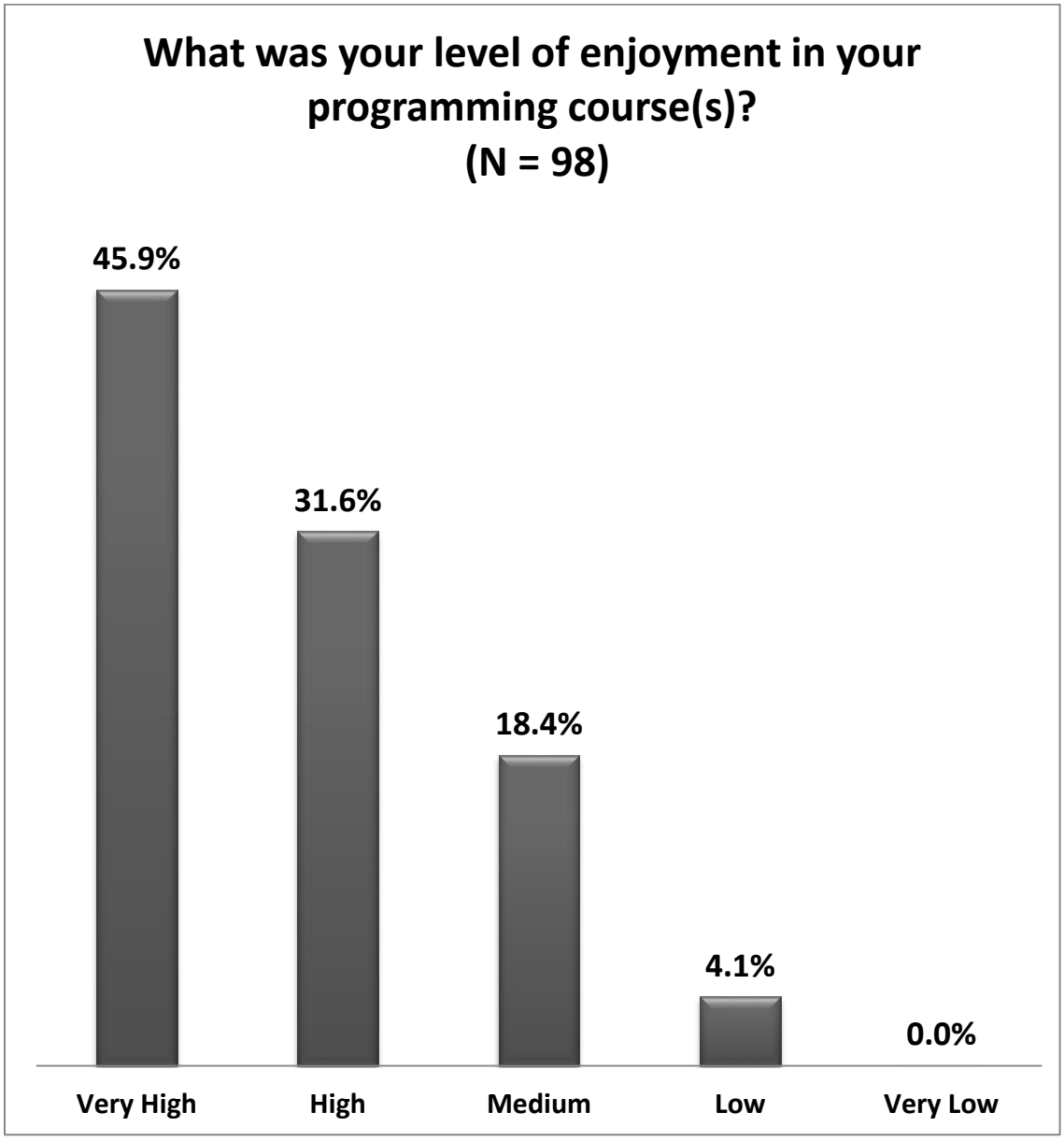
Appendix M

Research Question One: When Was Your First Programming Course?



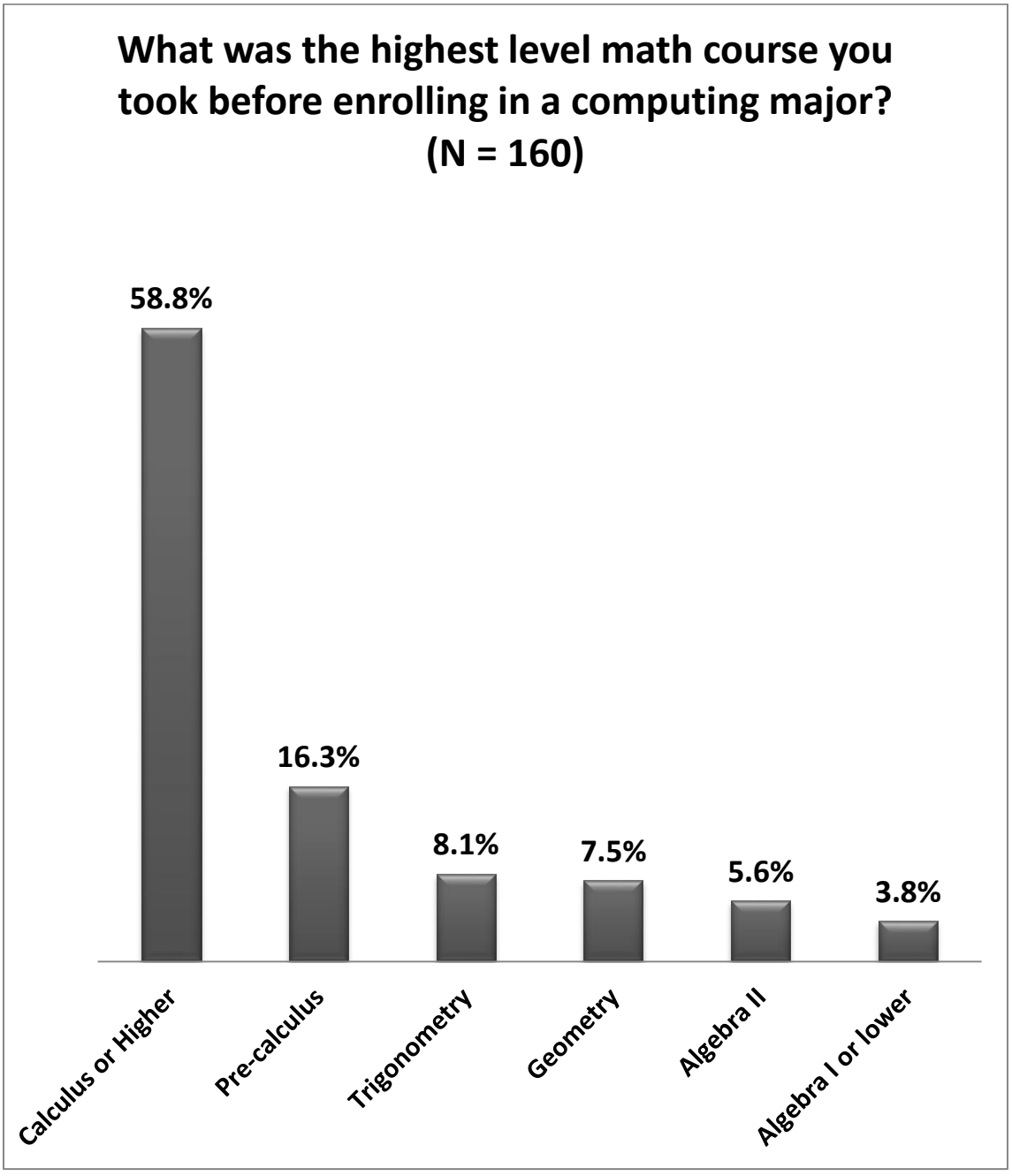
Appendix N

Research Question One: Programming Enjoyment



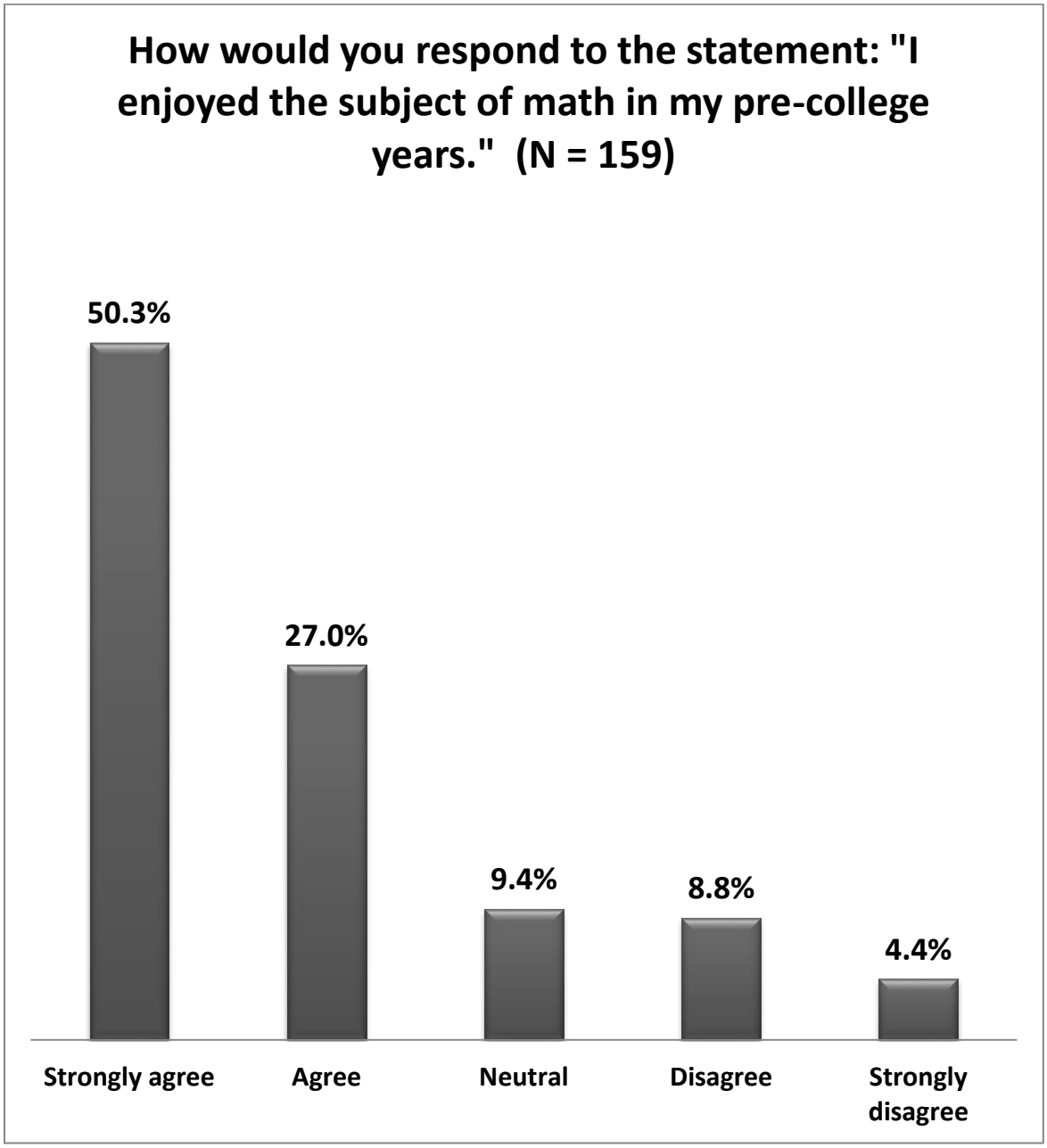
Appendix O

Research Question Two: Level of Math Skill



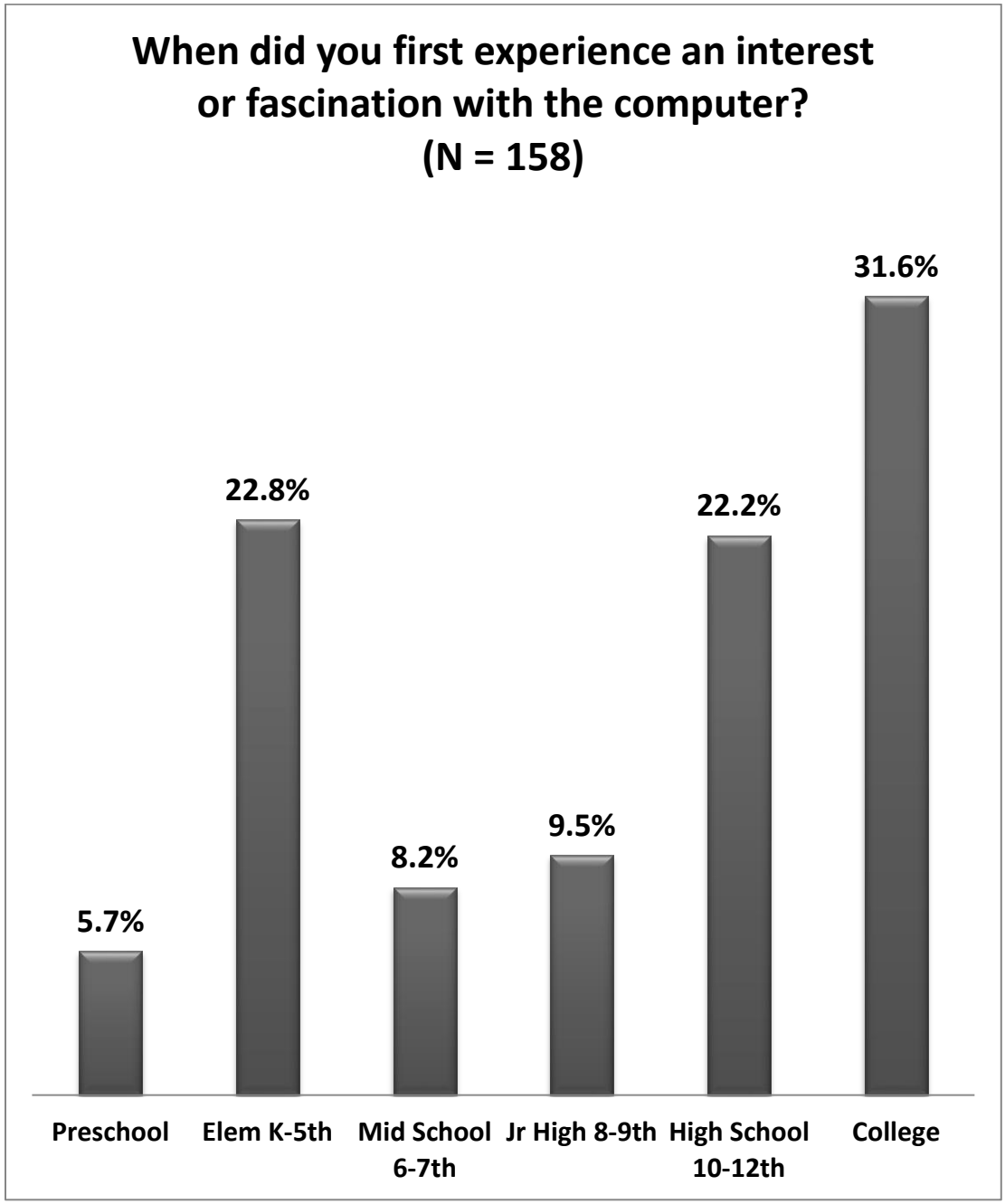
Appendix P

Research Question Two: Level of Math Enjoyment



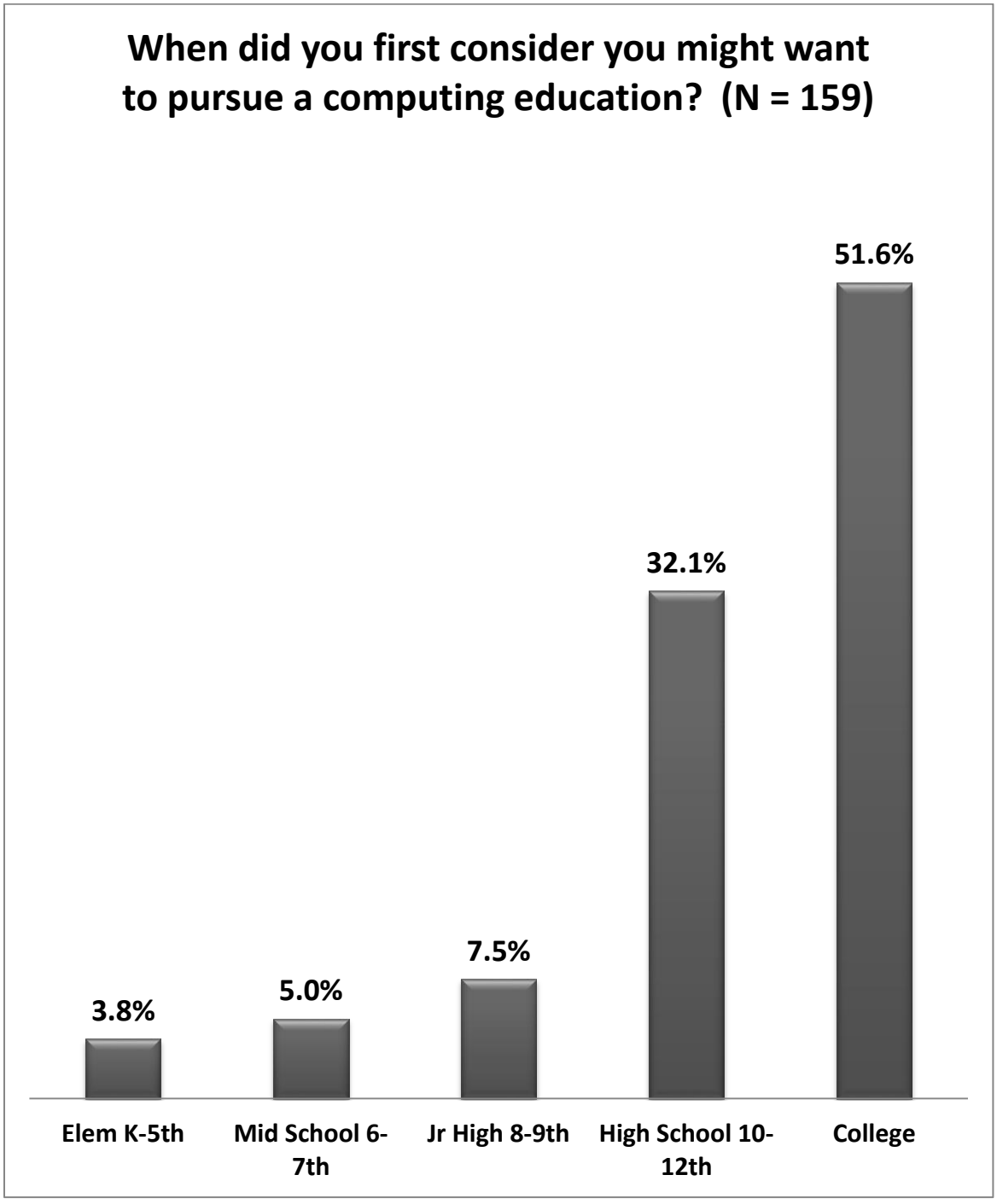
Appendix Q

Research Question Three: Interest or fascination with the Computer



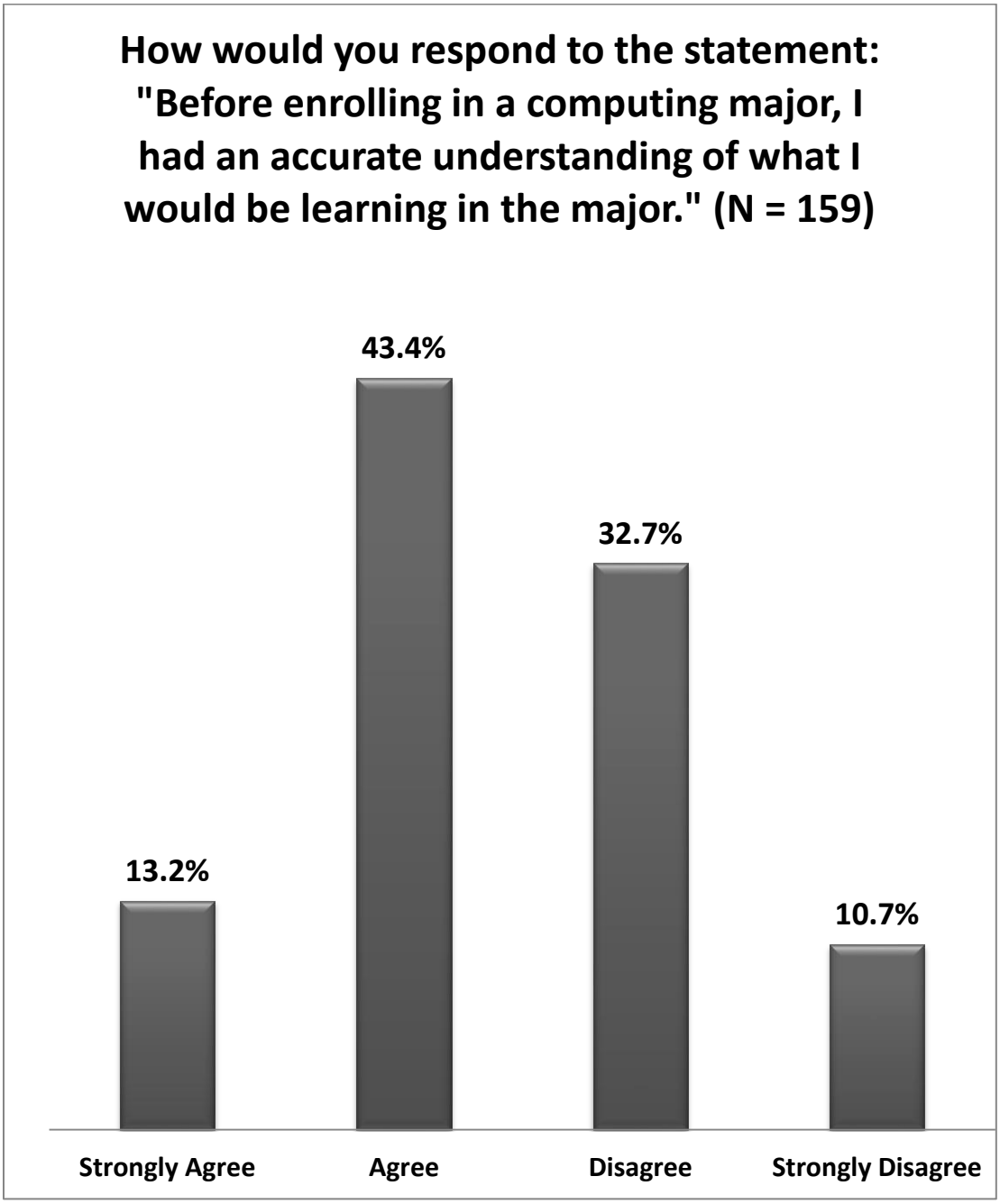
Appendix R

Research Question Three: Consider a Computing Education



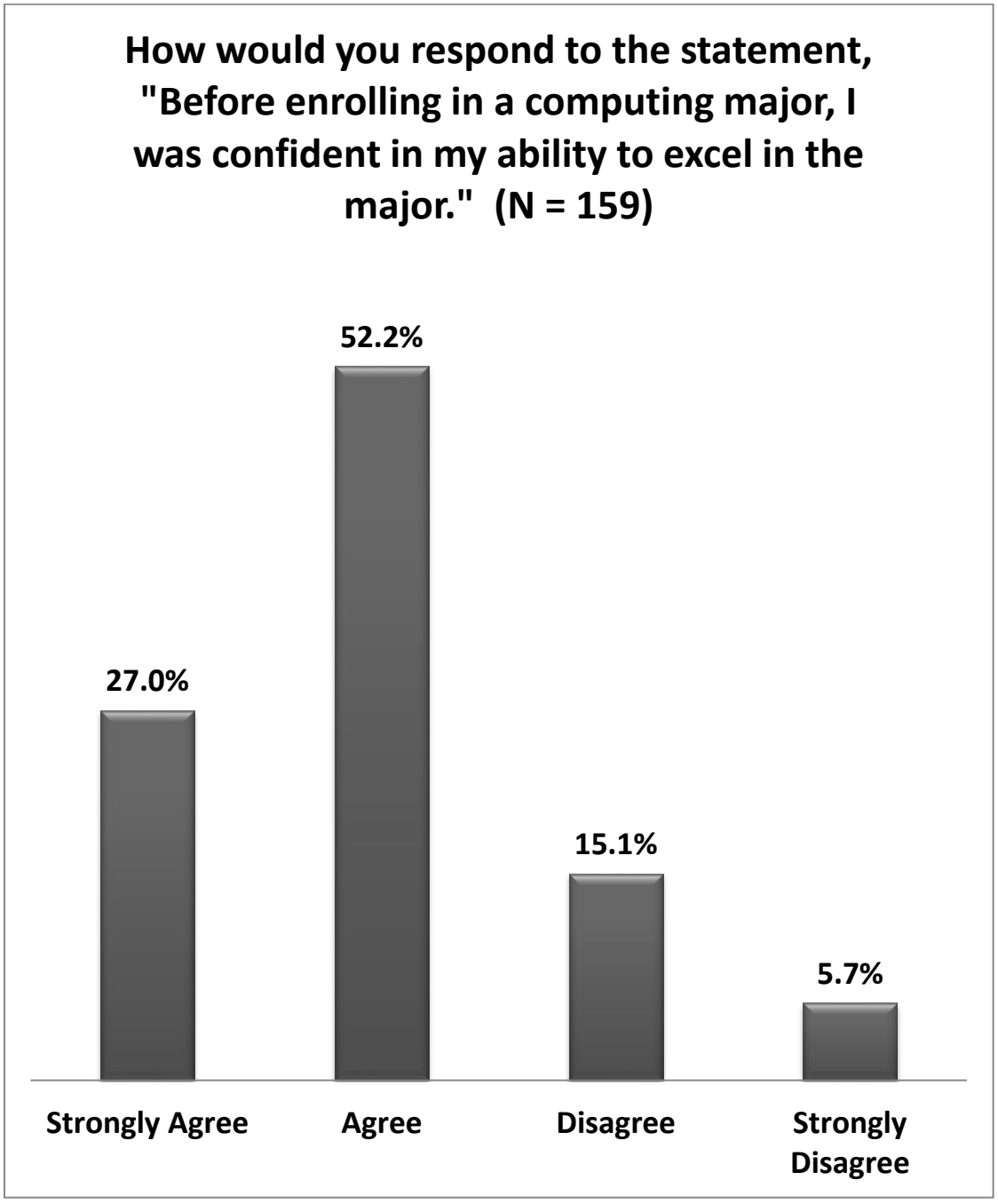
Appendix S

Research Question Four: Level of Understanding in Regard to What is Learned in a Computing Major



Appendix T

Research Question Five: Self-Efficacy Level Prior to Enrolling



Appendix U

Research Question Six: Pursuing a Computing Education: Extrinsic and Intrinsic Motivators

Factor (E-extrinsic, I-intrinsic)	Very Important	Somewhat Important	Somewhat Unimportant	Not Important
E-Excellent employment opportunities after graduation	66.7%	23.3%	9.4%	0.6%
I-Computing field seemed interesting	61.8%	32.5%	5.1%	0.6%
I-Enjoyment of computers and technology	59.1%	34.0%	3.8%	3.1%
E-Future in computing would be financially rewarding	52.6%	30.8%	10.9%	5.8%
I-Would be challenged intellectually	52.5%	36.1%	8.9%	2.5%
I-The work would be personally rewarding	48.4%	34.0%	16.4%	1.3%
E-Encouragement received	22.8%	43.7%	24.1%	9.5%
E-Challenge perception only men can succeed	16.0%	24.4%	22.4%	37.2%
E-Development of skills that would one day help society	15.1%	37.7%	32.1%	15.1%

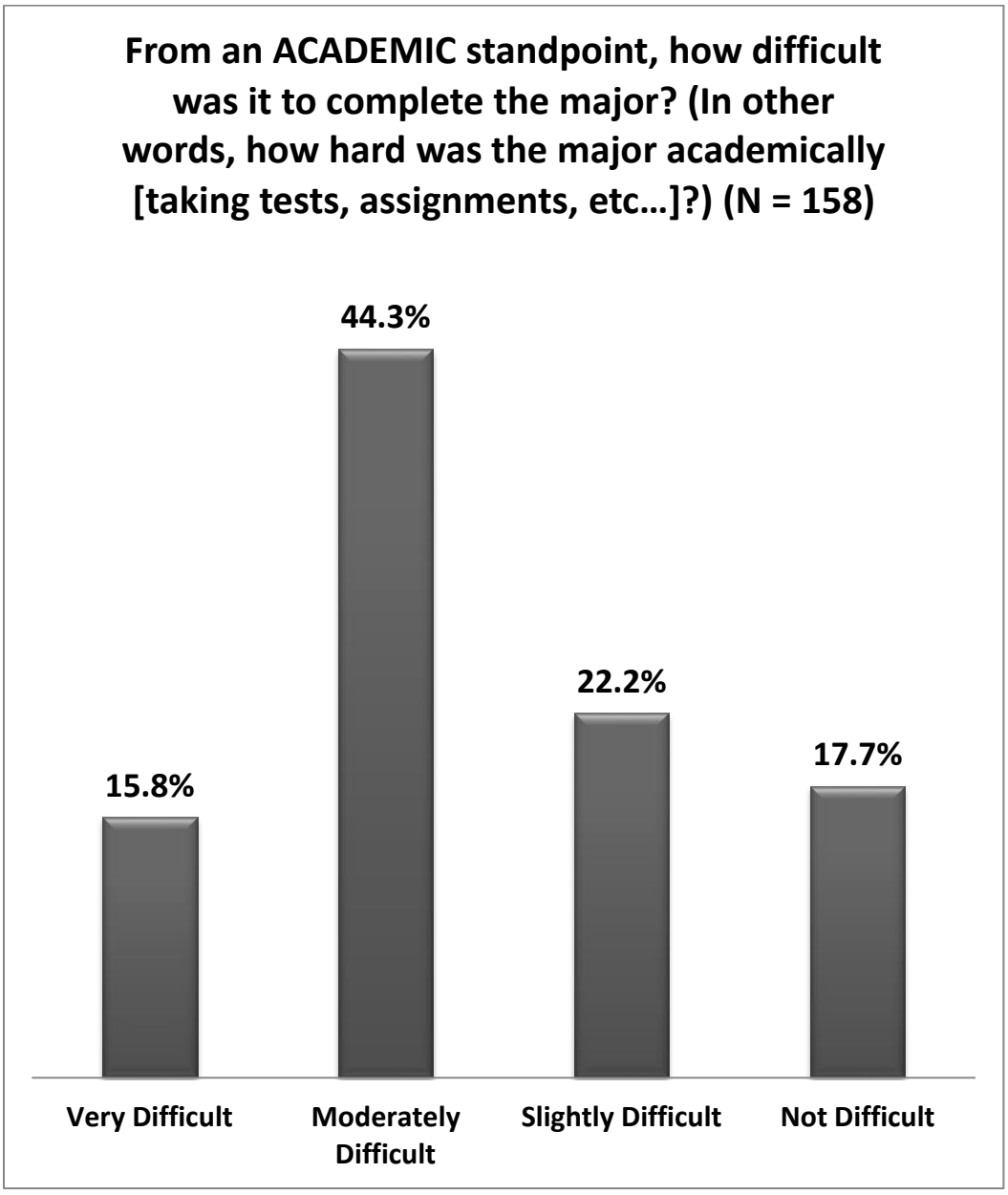
Appendix V

Research Question Six: Pursuit factor category placement

Categories:		freq
1) Future career and financial benefits		
	Promising and satisfying career prospects	48
	Field will provide financial security	32
2) Appealing aspects of computing		
	Programming	31
	Problem/puzzle solving	12
	Math component	11
	Logic component	7
	Creativity component	5
	Wide open and fresh field - always things to learn	6
	Structured and task oriented	1
3) Intrinsic needs met by computing		
	Interesting field	21
	Enjoyable	16
	Challenging	14
	Loved computers and technology	14
	Fun	3
	Geekiness - felt like I was at home	1
	Rewarding	1
4) Self-efficacy		
	Belief I am or could be good in computing	24
5) Outside influence		
	Recommended or encouraged by significant others	16
	Parental Pressure	2
6) Other factors		
	Helpful faculty	2
	Knew I would be one of few females	1
	Lack of other choices	1
	Friends were in the major	1
	Challenge perception that only men can succeed	1
	Class availability	1

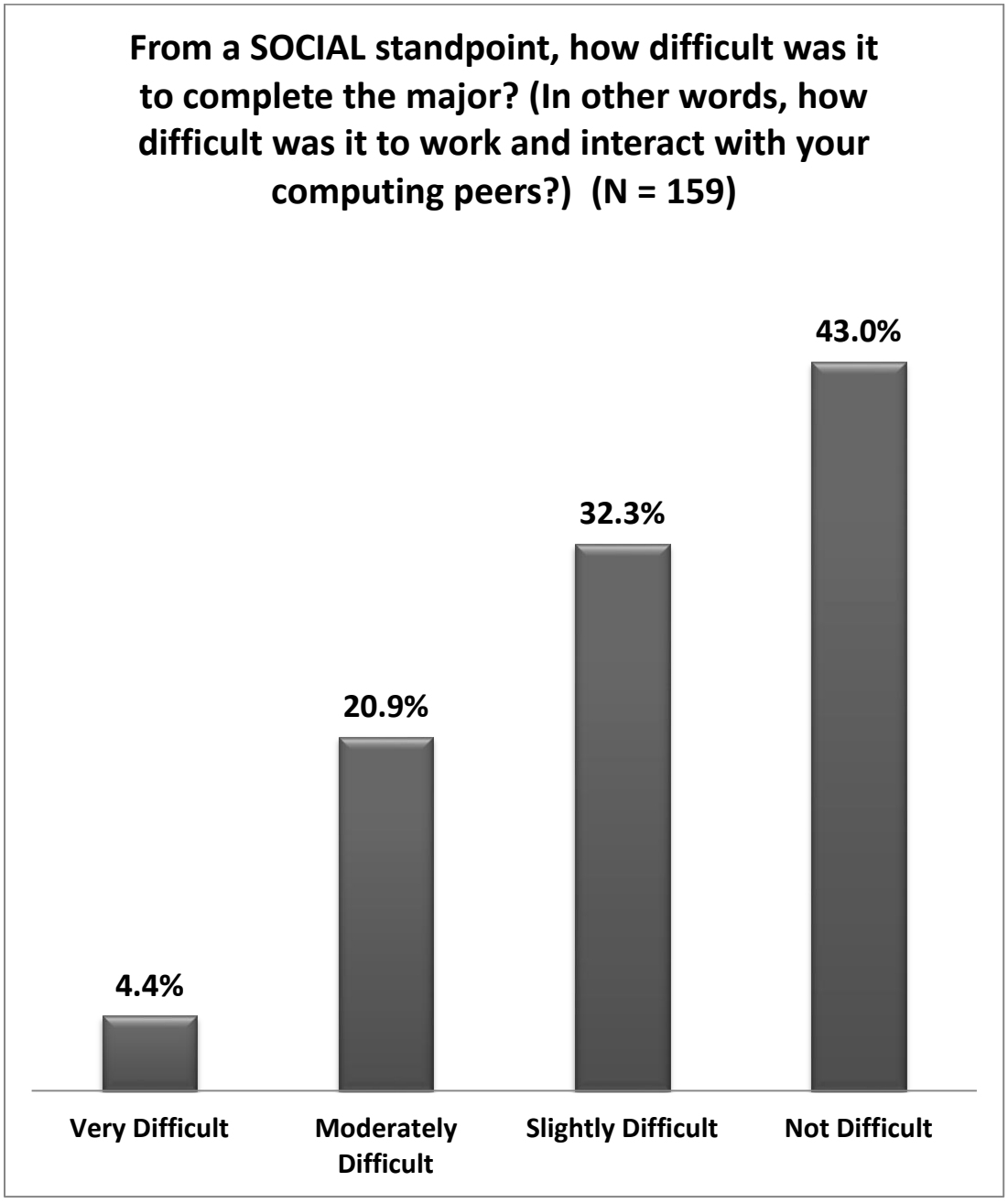
Appendix W

Research Question Seven: Academic Difficulty with Computing Major



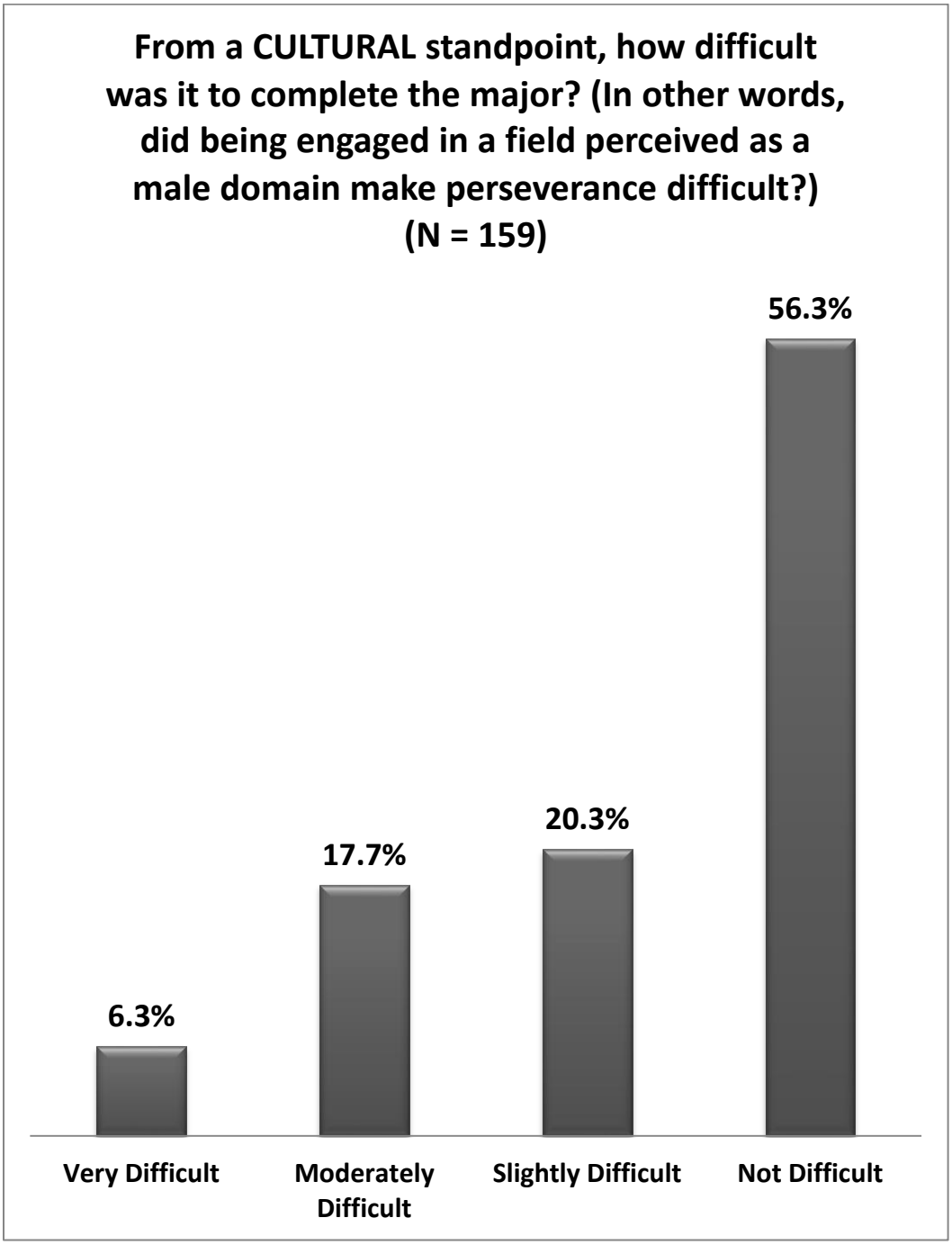
Appendix X

Research Question Seven: Social Difficulty with Computing Major



Appendix Y

Research Question Seven: Cultural Difficulty with Computing Major



Appendix Z

Research Question Eight: Factors that Encourage Persistence until Completion

Factor	Very Important	Somewhat Important	Somewhat Unimportant	Not Important
Academic Success	65.2%	31.0%	3.8%	0.0%
A hard work ethic	63.1%	31.2%	5.1%	0.6%
Able to manage the stress of the major	47.8%	41.4%	8.3%	2.6%
Seeing a purpose in computing	46.8%	32.9%	10.8%	9.5%
Faculty Support	43.7%	38.0%	12.0%	6.3%
Relevant Subject Matter	42.4%	43.7%	8.9%	5.1%
Receiving Encouragement	41.1%	38.6%	15.2%	5.1%
Making friends within the major	31.7%	34.8%	20.9%	12.7%
Being allowed to collaborate on assignments	22.8%	36.1%	19.0%	22.2%
Demonstrate women can succeed in the field	19.6%	26.0%	26.0%	28.5%
Having female role models	13.5%	21.8%	31.4%	33.3%

Appendix AA

Research Question Eight: Persistence Factor Category Placement

Categories		freq
1) Inherent character traits		
	High Self Efficacy (ability to do the work)	29
	Determination to finish and succeed	28
	Personal pride to finish a goal	25
	Hard work ethic and effort	23
	Responsible (did homework, went to class, self disciplined, balanced life and work, time management)	18
	Committed	16
	Unafraid to seek help when needed	4
	Sheer stubbornness (wouldn't quit)	2
	Helped others succeed	1
2) Personal benefits received from the major		
	Loved the work and brought a sense of accomplishment	27
	Personally and financially rewarding career awaits	26
	Subject matter enjoyable, relevant and fit my interests	24
	Major wasn't difficult, stressful or frustrating	17
	Major was fun	4
	Felt like I fit in	2
3) Encouragement, help, and support from others		
	Encouragement, help, support from faculty, friends, family, advisors, role models, women support groups	43
4) Making friends, building relationships		
	Establishing relationships/friendships	27
	Collaborative opportunities to learn from others	13
5) Other reasons		
	Didn't want to lose my financial aid	1
	To late to change to another major	2
	Not let my parents down	1
	Good financial support from government	1
	Lenient academic rules	1
	Didn't want to be a failure	1
6) Well prepared before entering major		
	Well prepared to enter major	4
7) Working in the field while enrolled		
	Worked in field while enrolled in major; internships	3

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