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SECURING THE PIPELINE: INCREASING WOMEN IN COMPUTER SCIENCE THROUGH INFORMATION SECURITY CURRICULUM

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ABSTRACT

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The percentage of women in computer science has not improved since the late 1970's. The major factors contributing to the lack of women obtaining computer science degrees have been identified. Case studies based on undergraduate computer science programs have shown that the admission and retention of women can be significantly improved by altering the teaching style, curriculum structure, and admission criteria of the program. The absence of women in computer science exasperates the current unmet demand for information security professionals. Augmenting an undergraduate computer science program with a minor in information security could not only help train more information security professionals but also attract and retain more women in computer science due to its interdisciplinary nature. In this thesis I have outlined an example curriculum for an undergraduate minor that meets the structure, style, and attraction recommendations that have shown to be successful in recruiting and keeping women in computer science.

CHAPTER 1 - THE LACK OF WOMEN IN COMPUTER SCIENCE

Women in Computer Science Programs

The number of women graduating with computer science and related degrees is disproportionately lower than that of men. It is a well-known problem that the ratio of women to men in computing diminishes from early education to the workforce; this phenomenon has been called a shrinking or leaky pipeline (Camp, 1997; Thom, 2001; Borg, 2002; Margolis, 2002). The percentage of women who receive degrees in computer and information science in the 1999-2000 academic year was roughly 28.1% for an undergraduate degree, 33.1% for a Master's degree, and 15.4% for a PhD (Bryant, 2000; NCES, 2002). These numbers persist despite the fact that in 2000, a full 56% of undergraduate degrees were granted to women (Carnevale, 2000). This number has been rising for the past several decades, but the percentage of women in computer science has continued to decline (NCES, 2002). The trend was predicted to continue downward for the next several years (Davies, 2000), and so far that prediction has been correct.

Figure 1 shows the percentage of women obtaining computer science degrees in the Unites States since 1975. The highest percentage of women graduating with computer and information science degrees was 37.1% in 1984, which declined through the 1980's, reaching 29.9% in 1990 (NCES, 2002). The number continued to slowly dwindle down through 28.4% in 1994 and then to its most recent low of 26.7% in 1998 (NCES, 2002). In 2001, there were 41,954 bachelor degrees granted in computer and information science. Only 27.7% of those (11,607) were granted to women (NCES, 2002). Although the percentage for advanced degrees in computer science is slowly rising, no significant improvement has been made in undergraduate degrees since 1979 (NCES, 2002). Despite the rise in awareness of the problem in higher education, these numbers show, at best, that the pipeline is not getting any worse. The fact that it is not getting any better is a serious problem that needs to be addressed.

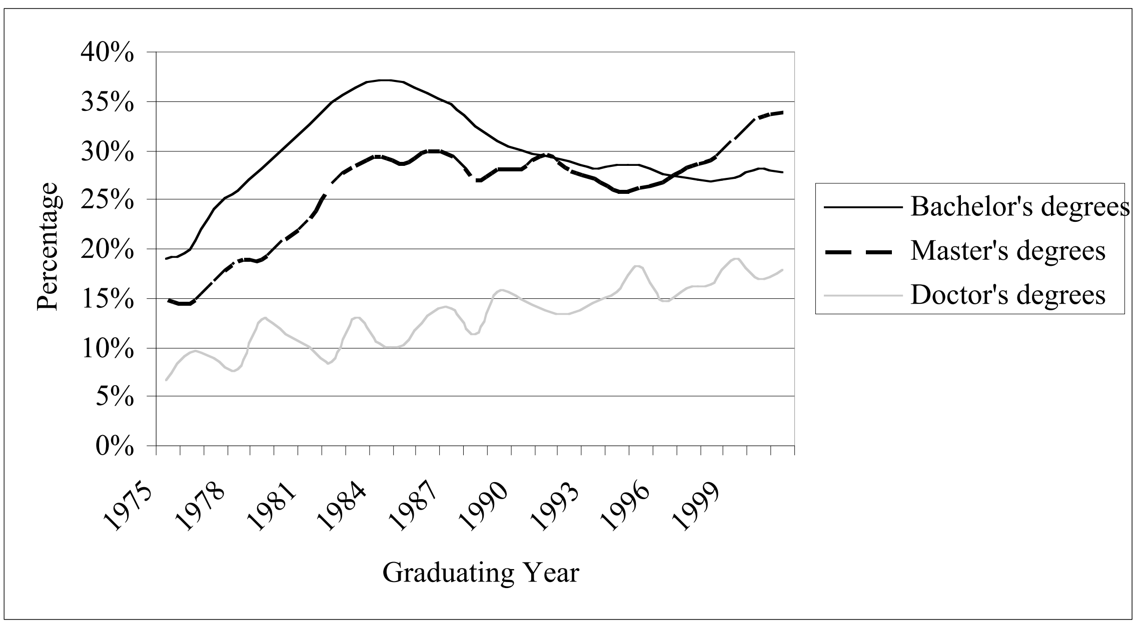

Figure 1. Percentage of computer science degrees conferred to women by year. Data taken from NCES 2002.

The repercussions on women being underrepresented in the field of computer science are many. The lack of women obtaining computer science degrees is a threat to the well-being of many women, the professional and academic health of computer science, and the US economy.

Effects on Women

One major component of the negative effect of women avoiding computer science is financial well-being. According to the fall 2004 survey by the National Association of Colleges and Employers (NACE), computer science bachelor degrees pay on average $49,036 (NACE, 2004). This is the third highest paying undergraduate degree in the United States, behind only chemical ($52,530) and computer ($51,297) engineering. In the biological/life sciences, where women tend to dominate men in degrees obtained, the average salary was only $29,629, 60% of the starting salary of computer science graduates (NACE, 2004). The gap in financial compensation also exists along gender lines within the IT profession. In a 1998 survey of IT professionals, the average compensation for men was $64,000/year. It was only $38,000/year for women (Pepe 1998).

Some would argue that the difference in salary between men and women is simply the result of choices that women make for themselves and that there is no need to intervene because one cannot dictate choice. The simple decisions women make may move them away from the field of computer science and away from high paying jobs within the field of information technology. Women may have obtained a non-technical degree, one where men do not dominate and they feel safer or more secure. They may choose to have children and take extended leaves or only work part-time. The critical flaw of this argument is that it ignores the power bestowed on men by the choices of the women. For every woman who moves away from a high paying a job there is a man ready to take her place. "Those who benefit from the status quo always attribute inequities to the choice of the underdog" (Crittenden, 2001).

Furthermore, women do not make their choices in a vacuum. Many factors go into making a decision as complex as what field of science or arts to study. Personality, prior experience, ability, personal preference, and financial ability all have weight in what major an undergraduate may choose. Social factors and gender schema affect the choices that men and women make every day, from what to wear to which sports to play. As many of these factors may be tied to gender, each may contribute to the lack of women in computer science. The social ramifications on women in computer science will be discussed in detail later in this thesis.

If more women "choose" lower paying fields they run the risk of entering lifelong relationships at a serious social disadvantage. In general, most families will attempt to maximize their income. The partner who makes the most money will usually have job security and have more power when it comes to decisions such as where to live or when to have children. With a tax code that penalizes married couples, there are diminished benefits of having a small second income. This pressures women into leaving their jobs to stay home. While some traditionalists may still feel that women should stay home and raise children, most people today recognize that women deserve to have the same opportunities in life as men. The act of pursuing fulfilling, financially rewarding careers is part of that realization. Dismissing the inequity as a "choice" benefits men while disregarding the position of women.

Effects on the Economy

The decline of women in computer science not only affects women but also has a profound impact on the United States economy. After the internet boom of the 1990's, the world economy saw a tremendous increase in the use of computers in business. Today no company can operate without computers, and the demand for software development, computer support and information technology staff has increased dramatically. There were only 1.2 million IT professionals employed worldwide in 1988, compared to 2 million in 1997 in the United States alone (Freeman, 1999). This increase in demand for IT professionals continues to grow and is not currently being met. The lack of available IT workers is well documented and has been attributed to low student demand for computer science and related degrees (Freeman, 1999; Balcita, 2002; McDonald, 2004).

Both the Federal government and private industry are concerned with the lack of women in information technology. In 2002, Connie Morella, a congresswoman from Maryland, cited a lack of skilled women, minorities and persons with disabilities as a serious threat to the future of the US economy. She noted an increasing demand for science, engineering and technology (SET) jobs, and that a skills shortage will severely hamper US economic growth. "Barriers exist today throughout the [science, engineering and technology] pipeline, from early education through higher education to the professional workforce [for women, minorities and persons with disabilities]" (Morella, 2002). Industry experts are equally concerned with the decline of women obtaining computer science degrees, citing new homeland security concerns and the eminent retirement of the baby boomers as upcoming factors contributing to the demand for skilled IT professionals in the United States (McDonald, 2004). These experts include

Rick Rashid, senior vice president at Microsoft. "You look at the national statistics [of women in computing]" he says, "and you just have to be appalled." Wayne Johnson, executive director of HP's university relations worldwide, agrees. "If you don't have half the U.S. population participating, you have a tremendous gap in filling these needs. What we're doing here is creating a disadvantage for ourselves as a nation." Recent estimates place the cost of the shortage of women in computer-related collegiate programs to the IT industry at $4 billion a year (Women's Educational Equity Act Resource Center, 2002).

Increasing the number of students in computer science would help address the shortage of highly-skilled IT professionals. As demand and job opportunities have increased, students have had more incentive to enter computer science. As this has happened, however, the percentage of women in computer science has stayed relatively steady or even dropped (NCES, 2002). The current growth of computer science graduates is not sufficient, so additional ways must be found to draw more students into the field.

Addressing the lack of women in computer science could potentially draw huge numbers of new students into the field. Based on the numbers published by the NCES in 2001, there would have been almost 14,000 more people graduating with computer/information science degrees if the number of women in computer science were even 45% of the total. This would result in a net increase of 33% over the total number of graduates with the ratio as it was. Women are a huge untapped resource for the US economy, and any improvement in female student enrollment stands to have significant gains for the Unites States.

Effects on Computer Science

Computer science research and development would benefit if more women pursue computer science as their field of study. One benefit is a very practical one: there is a threat in computer science education that there will not be enough faculty personnel in the coming years to teach computer science. Not only is the current rate of Ph.D. graduates not sufficient to meet the demand for faculty, but a high percentage of graduate students are nonresident aliens who will leave the country after receiving their degree. To make matters worse, many computer science students choose to leave academia and work in industry (Bryant, 2001). With only 18% of the postgraduate degrees in computer science going to women (Bryant, 2001), improving the percentage of women would go a long way to meeting the demand for personnel. The first step in doing this is improving the percentage of women receiving undergraduate degrees in computer science.

Beyond simple numbers, however, there is another intangible benefit to having an equal proportion of women and men in computer science. The field of computer science is varied and highly complex. While many problems have been solved, every day research reveals yet more significant problems that the next generation of researchers must address. Among these are NP-completeness, distributed computing, and digital rights management. As new and unique problems arise, there is a need for new and unique solutions to those problems. An under-representation of any group, whether it is in women, minorities, or disabled persons increases the risk that an important insight or perspective may be lost. We do not want to miss another female pioneer like Ada Lovelace or Grace Hopper who may make a key contribution to computer science.

Women have a different perspective on technology, and that will have an impact on what is studied, how things should be built, and what receives funding (Borg, 2002). One California communications firm discovered this when their voice recognition software designed for emergency response at a hospital was failing. Even though most of the users were female nurses, the testing was done mostly by and for men. When the system was recalibrated using women's voices, the system worked fine (McDonald, 2004). If women are not a part of creating the technology of the future, women will be at a disadvantage using the technology of the future.

Conclusion

Computers have become an integral part of the life of the United States. The advent of the internet and related technologies has redefined how we think, act, and conduct business. The increase in demand for computing professionals, both in the private and educational sectors, has created a large number of high paying jobs while helping to enrich many lives and enhance the economy. The participation of women in this movement has been disappointingly low. The ratio of women to men in computer science is low and not improving, which has severe repercussions to women, the economy, and the field of computer science itself. Many women are denied access to high paying jobs and the benefits they bring with them. Missing these opportunities places women at a social disadvantage. The lack of women in IT is a major hindrance to the US economy which has a huge unmet demand. Computer science is facing a potential crisis in finding enough qualified professors to teach the next generation of students, and women comprise only one fifth of computer science doctorate students. The lack of women in computer science is a major problem that must be addressed.

CHAPTER 2 – LEAKS IN THE PIPELINE

There is no single solution that will solve the problem of the leaky pipeline for women in computer science. Research has shown that there are many contributing factors to why so few women choose to pursue degrees in computer science and related fields. Many of these factors feed into each other, building from simple interactions in childhood to complex pressure and expectations in college. Each of these must be identified before a meaningful solution can be presented. I characterize the factors into several, mostly non-overlapping categories: childhood experiences, social influences, computer gaming, pre-college encouragement, computer experience, self-confidence, attitude, and mentoring/role models. The following section discusses each of these aspects using examples from current work in the field of study.

Childhood Experiences

A person's earliest experiences with computers may have a profound effect on his or her educational choices later in life. As early as kindergarten it seems that boys dominate computer use. While girls skillfully use computers for word processing, boys tend to spend more time on them playing games (Margolis, 2003). One possible explanation for this difference at such an early age is that at home, computers tend to be more accessible to boys than girls. In 1993, a study of families in New York found that in more than half of the cases families placed their computer so that it was primarily accessible by the father or the son, such as in the son's bedroom (Giaquinta, 1993). The placement of a computer somewhere inaccessible to daughters might send the message that it is not for them and divert their attention elsewhere.

Studies have also shown that fathers play with their sons 50 percent more than with their daughters (Goldstein, 1994). If fathers are exposing their sons to computers more than their daughters this could have a direct impact on the gap in interest and ability in computer science. Munira Rahemtulla, President of Stanford University's chapter of the Society of Women Engineers, was taught about computers from an early age by her father. "When I was really young," said Rahemtulla, "my dad brought home our first computer. He encouraged me just to play." As in this example, encouragement in early childhood can have lifelong repercussions.

This perceivable difference in the home extends to computer labs at school. It has been shown that in computing environments, boys tend to act as hosts while girls tend to act as guests (Elkjaer, 1992). Establishing computers labs and areas as "boy" places will have a lasting impact on gender association with computers. If a child at a young age feels unwelcome or out of place in a computer lab that individual will miss opportunities to learn about computers. Providing inviting and secure access to computers for young children of both sexes will help prepare them for a lifelong use of computers.

Social Influences

It is inescapable that we live in a society that views the two sexes as two separate genders. In a world where gender is abolished and both sexes were completely equal, the problem of women in computer science would not be an issue. Assuming that total gender equity is currently unattainable, we must accept that there are social differences between men and women. The differences between the genders is a hotly debated topic. Most people either believe that we have inherent traits that are innately male or female (such as aggression, compassion, motherly instinct), while others believe that gender is primarily socially constructed, an artificial way of acting that has been defined for us by society. Arguing which is truer than the other is not important here because, no matter the source, there currently is a difference in mindset between men and women. It is also true that not as many women are entering the field of computer science as men. Acknowledging this, the specific social factors that are holding women back from obtaining computer science degrees should be identified. It is important to note, however, that factors that exist in the United States may not apply to other countries, as they may have very different social structures (Galpin, 2002).

How the advertising industry portrays computer enthusiast is one social pressure on women. Popular images of computer programmers and computing professionals imply that computers are for "nerds" and their users are only men (Makoff, 1989). Associating computers with masculinity is more than apparent today than ever. The media sends many small but certain messages to young women that being interested in computers is something only boys do. During adolescence especially, when boys and girls try to fit in with their peers, this pressure can dissuade talented young girls from learning about computers. It has been found, however, that if parents assure their daughters that they can use computers and still be feminine it can have a profound positive impact on their computer use and attitude (Miller, 1999).

The media also holds a strong place in influencing young girls. Most computer magazines through the 1980's portrayed only male computer users being avid enthusiasts (McCormick, 1991; Struck, 1985). A survey of high school girls found that three of the top six reasons why they are not interested in computer science were influenced by the media ("women have other interests", "negative media", and "too nerdy") (Jepson, 2002). The constant reinforcement of the male computer geek stereotype by the media is a de-motivating factor for otherwise interested female computer users to pursue a computer science degree. Research in 1985 found that women had a negative view of computers, while men had a more positive association, which led to a decline of interest among the current generation of college-aged women (Kiesler, 1985).

Society dictates that women place more value on raising a family than men (Crittenden, 2001). There is a perception that computer science careers require a larger time commitment and will interfere with personal life more than other careers. Computer science careers are in this way different from other time consuming professions, such as careers in medicine, which do not have the same associated lack of family life (Miller, 1999). Based on these perceptions, computer science is being portrayed as an unattractive field to people who want to stay home and raise a family. Because the gender norm is for women to care for the family, these pressures disproportionately affect women.

Social influences are constant and pervasive. They can come from the media, teachers, friends and family. While it is impossible to control all social factors that affect women going into computer science, identifying the most influential ones is the first step in being able to address them.

Computer Gaming

Playing games is an important part of social and skill development and may also be a factor in why so few women choose computer science. It is virtually undisputed that computer games are primarily made for and played by boys. A 1987 survey of high school students found that 90% of the students who played computer games before and after school were male (Becker, 1987). In 1997, boy-targeted games dominated the market (Beato, 1997). In a study of roughly 450 high school and community college students, men were significantly more likely to use computers for games and entertainment. All other categories (social use, educational/work related, and total use) were so close between men and women as to be statistically insignificant (Creamer, 2004).

Women respond to different video game qualities than men. One study discovered that young women prefer games that feature social interactions and relationships between characters, puzzle-solving, and collaboration rather than games that depend on reflexes and competition (Gorriz, 1997). These changes have come into effect in the past several years with the wildfire success of *The Sims*™ and its recent sequel, *The Sims 2*™, both published by EA Games®, in which the player controls a virtual world. The player can design and build houses, manage interpersonal relationships and model entire neighborhoods. These games have been very popular and embrace many of the aspects of gaming that Gorriz found were appealing to women. However, most women of college age today grew up in a world where gaming was primarily for boys.

Psychologist Elizabeth Debold wrote that computer games appeal to boys because they are made by boys and based on male fears and concerns. They reassure men of their masculinity by helping them resolve their fears with large amounts of violence and stereotypical "male" characters (Debold, 1997). This has been reflected in available computer games. A survey of rental games available in 1996 found that, of 259 games available for rent, only three had women on the boxes at all, and only one had a female protagonist (Chaika, 1996). By this male domination, a computer game domain is created that embraces young men while stigmatizing young women. Those who do decide to play the games are inundated with "male" messages and stereotypes that they are otherwise told do not apply to them. These mixed messages may account for the lack of many women computer gamers.

Women are not avoiding computer games simply because they are on a computer. One of the first games aimed strictly at women was *Barbie Fashion Designer*™ by Mattel Media®. This game was a runaway success, selling more than 500,000 copies in its first two months (Beato, 1997). However, simply getting girls in front of the computer to play more games may not help the problem of women in computer science. When computer games appeals to gender stereotypes, it can hurt a young woman's expectations of success by re-enforcing the societal gender roles associated with them. This might hinder young women as much as help them (Huff, 2002). Since *Barbie Fashion Designer*™ others have emerged that do not rely on appealing to stereotypes to attract women, but present to them the aspects of gaming that they prefer.

In its first ten days on the market, *The Sims 2*™ sold more than one million copies (BizReport, 2004). This is evidence that demand by girls for computer games is still very high, but was not being met by available titles. Women want to play computer games as much as men, but have not had the same opportunities as them until very recently. Games such as *The Sims 2*™ allow exploration without stereotypes, unlike *Barbie Fashion Designer*™, which attracted women by using stereotypes to make young women feel more comfortable in front of the computer.

There is a tangible benefit to being interested in computer games. The extra time and interest in computers very likely had a dramatic effect on a whole generation of potential computer scientists. As a generation of young boys learned how to make their computers faster and more capable to play the latest games, they were inadvertently learning skills that would later lead them to study computer science. Software issues like driver support, installation methods, and even save game "hacking" are all opportunities for a person to teach themselves computer science related skills. Computer hardware requirements brought them inside the computer each time they wanted an upgrade to improve performance. As the number of games for women increases, and the number of girl gamers with it, this disparity will hopefully close and be less of a factor in attraction to computer science.

Pre-College Encouragement

Encouragement of girls in pre-college education has been found to be another significant factor in the pursuit of computer science by women. A lack of encouragement can dissuade otherwise talented young women from continuing to use and learn about computers. One aspect of this is the little encouragement for women to use school computer labs.

A national survey of high school students found that before and after-school use of computers was dominated by boys at 80% (Becker, 1987). One research study of a large, urban, mid-western high school also found that a small group of boys dominated the computer lab (Schofield, 1995). A separate study found the same thing in middle school: boys dominated the computer labs (Koch, 1995). All the way back to kindergarten this pattern of a male-dominated physical space is seen (Margolis, 2003). If school administrators do not take steps to ensure equal access to computing resources, they are discouraging young women from exploring computers. Opening up computer labs with assigned time for all students would help female students' access computers at school (Koch, 1995). Failure to make women welcome in computer labs both sends a message to them that computers are a "guy thing" and prevents them from attaining the same skills and experience that the boys acquire.

Teachers and guidance counselors can step forth and encourage women to pursue computer science courses. It would appear, however, that high schools across the country are not encouraging young women enough. In one Midwestern high school, it was found that the few women in the mid-level programming class were routinely teased and made fun of. None of these girls went on to the next level of computer science class (Schofield, 1995). Most of the jokes were aimed towards the girls' inexperience with computers or their gender. There was a noticeable lack of teacher intervention in these activities. Thus, through inaction, the teacher created a hostile environment for the female students. While this case study probably does not represent every computer science course, some evidence hints that it may be more common than not. Studies have shown that both male and female computer science teachers call on male rather than female students (Margolis, 2003). Young girls learn from this behavior that computers are something that boys know more about than girls.

The lack of encouragement by teachers is reflected in the academic accomplishments of women in high school. In 1999, according to the College Board, only 17 percent of those taking the advanced placement (AP) test in computer science were female. This was the lowest percentage for any of the AP tests, including chemistry, physics and mathematics. While there is no single reason for this, classroom dynamics and access to computer labs may play a significant role. Encouraging young women in school and after school to use computer would help close this gap in achievement.

Computer Experience

Prior computer experience has been shown to be a major influence on an individual's decisions to pursue computer courses in college. Clegg and Trayhurn, along with many others, discovered that men have significantly more experience with computers than women by the time they reached college (Clegg, 2000). A survey of men and women in introductory courses at Princeton and Rutgers found that academic performance in computer science courses was strongly tied to prior computer experience (Parelius, 1996). Many of the previous factors contribute to this inequality: parents promoting computer use at home for boys, computer labs with intimidating environments, a male dominated computer game market, and lack of enrollment and encouragement in high school computer science courses. Social factors may play into this as well, such as women viewing computers as nerdy or unappealing. The end result is that a lack of experience with computers is putting women at a disadvantage to men once they reach college.

Another possible explanation for women’s inexperience with computers is that most web sites, CD-ROMs, and other digital resources are not designed with the preferences of young women in mind. In a 2004 study, young women between the age of 13 and 15 were given time to browse popular teen websites and were then surveyed on what appealed to them about these sites. It was discovered that website preference was divergent along gender schema, although girls are not a monolithic group who all value the exact same characteristics (Agosto, 2004). It did find that content was geared more towards male preferences. This could contribute to the lackluster appeal of computers to young women.

Social involvement can mean significant improvements in a child's computer experience level. Mothers especially can show their daughters to be fearless about working on a computer which can lead to significant gains down the road (Adelson, 2002). Computer clubs can also be more receptive to women to help them explore their interest in computers. Suggestions have been made that, in order to help draw women into computer clubs, they should try to expand activities beyond playing networked games and having programming contests (Carlstead, 2002). Any way of helping to raise young women's experience with computers would positively contribute to their attendance and retention in college.

Self-Confidence

Possibly the single greatest factor of the leaky pipeline is a lack of self confidence in women regarding computers. At almost every step in the pipeline, self confidence will influence decisions on what activities to pursue, what classes to take, how much to work, and even if staying in computer science is the right choice. Studies have broken down contributing factors for confidence into four areas: performance and accomplishments, observing and learning from others, freedom from anxiety of work, and persuasion and support from others (Ambrose, 1997, 1998). A lack of computer experience makes women more vulnerable to problems of self confidence because they can not initially achieve the same levels of performance and accomplishment as men. With computer science often being a very solitary and disconnected field, women do not receive much benefit from the support of their colleagues. This can slowly erode away women's confidence throughout their academic careers.

Many women in computer science feel what has been called "the imposter syndrome" (Leveson, 1990). They feel that they do not belong, and this is reflected in their questioning of their own ability to finish work and participate in class. This problem is exasperated by sexist hazing by male students, which includes teasing and belittling based on prior computer knowledge (Fisher, 1997). While many women in computer science initially do lack the same level of experience as men, this need not lead them to drop out of the program. Many women who doubt their own academic talents do as well or better than their male counterparts in computer science classes (Fisher, 1997).

It is quite possible that closing the gap in computer experience and fostering a more understanding, responsive faculty would help women gain confidence in computer science. Providing support structures and peer-based learning could help address the four aspects of self-confidence. As higher levels of education are attained, work becomes more independent and less interaction between teacher and student is required. If a person has not established healthy self-confidence by then, they may be intimidated away from these pursuits even if they are highly talented and capable. This is one category that an institution such as a college can address to help its own female retention.

Attitude

Attitude is a direct motivational factor regarding choice of and perseverance in a college major. Naturally, a person who severely dislikes computers, ergonomically, functionally or otherwise will not want to pursue a major where they will have to use a computer often. Additionally, a person who views computers as nothing more than toys will not take them seriously enough to choose computer science as a field of study. A subtle change in attitude, from viewing computers as fun toys to exciting development tools, has brought many people to study computer science and continue on as IT professionals. Research has shown that this attitude is often lacking in women.

A survey was conducted on 800 senior-level men and women of all majors who were given laptops for all four years of college (McCoy, 2004). The purpose of the study was to determine the effect of having a laptop on attitudes about computers. Overall, the attitude about computers was roughly the same for men and women, both of whom viewed them as generally positive. Computer usage was also nearly the same for men and women (McCoy, 2004). Despite these similarities, men rated their expertise in computers higher than women rated theirs. It also discovered that women, more than men, felt that the laptop computer helped enhance their social lives (McCoy, 2004). This is revealing in that men had an attitude of control and understanding, while women felt it was more of a social tool for them to use.

Attitude towards the computing profession also clearly influences decisions on college students. Here, gender lines may become more clear and understandable. College-age women have also been shown to choose careers that directly involve helping others more often than men (Creamer, 2004). If being a programmer or working in an IT department is too far removed from helping people or seen as unemotional and detached, then it will not appeal to women as much as men. Advertising the humanitarian benefits of computer science to the public, such as improved healthcare, may help female students maintain a positive attitude about computer science and help them choose to stay in the field.

Mentoring and Role Models

Mentors and role models can have a tremendous positive impact on an individual pursuing a degree. A good role model can provide motivation, increase self-confidence, and help shape a person's attitude. A mentor can help a student choose the right classes, support them in times of trouble and difficulty and ultimately guide them through a program successfully. Unfortunately, there is a lack of female computer-related role models.

Silicon.com has an annual poll of 50 most important people in computing. In 2004, the highest ranking and singular woman in the list came in at number 21, Karen Price, CEO of eSkills UK. In a world where gender identification is innate in most people, having a role model of the same gender is important to be able to relate with him or her. College-age boys can associate themselves with Bill Gates, Linus Torvalds, or Steve Jobs, or any of the other many successful men in computer science. Women do not have access to as many highly visible individuals. The lack of high-profile women in computing may have a negative effect on female computer science students.

In addition to this, the few role models that are available to women may actually have their self-confidence undermined because they cannot relate to them. This is due to the fact that these women often had to overcome extreme challenges to get to where they are, or may be too distant or dated to be useful role models (Fossum, 1998). With no immediate female role models in a particular department, it is feared that women must reach too far and will not be able to find any role models at all. A study of several female undergraduates who attended a computer conference found that they were impressed and inspired by hearing presentations from accomplished women in the field (Francioni, 2002). Increased visibility of female faculty can help along these lines and provide readily available female role models for students.

Faculty have an important role to play as mentors to women in the first years of undergraduate education. If faculty could effectively reach out to female students, it could help them overcome some self-doubt and lack of confidence (Camp, 2001). For undergraduate physics, which has similar problems attracting and retaining women, establishing "four year" mentors for students had a very positive effect on retaining female students (Ivie, 2000). If faculty devote a portion of their time for female students, it would be well worth the extra effort to help maintain students in a computer science program.

Summary

Current research strongly indicates that from young childhood through their college education women face adversity and challenges in computer science that men do not. Through the complex manipulations of social influences, young children are separated into "boys" and "girls" and take on many associated traits. One of these traits seems to be an interest in computers, which is solidly in the realm of the masculine. This distinction makes many families and schools inadvertently steer young girls away from computers even as it pushes many young boys towards them. This continual pressure, however gentle, eventually affects the experience with, self-confidence about, and attitude of women regarding computers and computer technologies. The few women who do pursue an academic career involving computers quickly find a lack of mentors, unfriendly departments and a computer culture geared towards men. These factors result in many women changing their major and dropping out of computer science.

Each factor above is determined by disparate groups who act based on their own social, legal, and economic interests. This does not mean that there cannot be meaningful efforts to address the lack of women in computer science. Today children are being raised with more computers available than before. Schools today have plentiful labs where young boys as well as girls can have equal access to computers. Organizations and companies are campaigning for more positive female role models, computer games, and methods of attracting women into computer science. Colleges can and should take action to help increase their admission and retention of female computer science majors and there exist concrete, tested methods to help accomplish these goals.

CHAPTER 3 – PATCHING THE PIPELINE AT COLLEGE

The problems that have been identified in the pipeline at first glance appear overwhelming. Women of every age are affected by social pressures and industries that act based on their own interests and motivations. Despite recent efforts, including increased scholarships for women, outreach programs and recruitment efforts, the ratio of computer science degrees conferred to women has remained largely unchanged. Only in the past several years have truly comprehensive solutions been in place. These efforts have come from organizations devoted to women in computing and research conducted by concerned college programs.

Organizations Helping Collegiate Women

Many groups exist that are devoted to helping female students succeed in computer science. There are three main organizations who have reached out to women in computing: The Association for Computing Machinery Committee on Women in Computing (ACM-W), the Committee on the Status of Women in Computing Research (CRA-W), and the Institute for Women in Technology (IWT) (Gabbert, 2002). These organizations create a space for women in computer science to socialize, learn about computers, and find mentors and role models to help improve their attitude and self-confidence. They also conduct research on women in computing and help raise awareness of issues and educate the academic and world communities about women in computing. Education is an important part of addressing many of the components of the leaky pipeline. Colleges can apply the results of this research to directly help solve the problem within their own programs.

College Case Studies

Many colleges have conducted their own studies into the problem, producing suggestions and plans of action. These solutions focus on improving both admissions to computer science departments and the retention of female students through graduation. Academic institutions are unable to have direct impact on many of the leaks in the pipeline. Instead they must focus on the aspects which they are able to control, specifically admission requirements, accounting for varying attitudes and experience, and providing accessible role models and mentors. Early efforts in these areas were less successful, but the latest research has produced some eye-opening results.

SUNY Geneseo

One early study was conducted at SUNY Geneseo. After recognizing that while 50% of all students in introductory computer science courses are female, less than 25% of computer science degrees were conferred to women (Scragg, 1998). Researchers surveyed the roughly 300 men and women who took the entry-level computer science courses that were open to all students. Scragg created questions that focused on six hypothetical barriers to women in computer science:

1. General social barriers (friends and family) discourage women from pursuing computer science.
2. Women face more crises of self-confidence over their performance in computer science than men do.
3. Women don't have as much chance as men to contribute ideas in class, and their contributions are under-valued when made.
4. Women believe that computer science is too dominated by men.
5. Women believe that math is an important part of computer science, yet suffer more than men from math anxiety.
6. Women feel more strongly than men do that they want to raise a family, but that a career in computer science is incompatible with this goal.

Only two questions yielded statistically significant differences in results: self-confidence and male domination (Scragg, 1998). They also discovered that women surveyed had significantly less computer experience than men coming into the field, and that most women in the computer science courses did not plan to major in computer science at all (Scragg, 1998).

The authors noted that their sample size was small and the survey would have to be expanded to be more valid, but still suggested that the problem may be one of outreach and recruitment. The plan of action resulting from the research consisted of three major points: create an outreach program to public schools to help increase interest in computer science, work with schools to make sure they present computer science to young students, and support mentoring programs for women to help them enter the field. No changes to curriculum or other departmental changes were suggested to help promote women in computer science.

Scragg concluded that the pipeline problem within a college may be addressed simply by admitting more women and sustaining the same rate of attrition (1998). Other research suggests that this solution may improve things but is incomplete. While increasing the admission of women might help get more women into computer science, it will not have a significant effect on the leaky pipeline (Borg, 2002). Forcing more women through the pipes will only result in more women dropping out, and further the impression that men, not women, belong in computer science. More in-depth research projects have been conducted that suggest colleges can make a significant positive impact on the women entering and staying in their computer science through changes to the program itself.

Furman University

One of the first set of suggestions for a computer science department to change came from a study at Furman University by Kevin Treu and Alisha Skinner. This report was significant because it focused entirely on changes within the department itself, while most previous research suggested mentoring programs, pre-college workshops, and the involvement of women in extracurricular activities (Treu, 1996). They interviewed staff and observed classroom dynamics to discover if there were anything present that deterred women. The researchers concluded that a more gender neutral environment would significantly benefit women. To this end they made ten suggestions to their own computer science department. In no particular order, they were:

1. Address female students by name as often as men are addressed by name.
2. Establish eye contact equally with men and women.
3. Avoid gesturing more often when men respond to questions or make comments.
4. Refrain from interrupting female students more often than males.
5. Allow women as much time to answer questions as the men are allowed.
6. In those instances when a woman can't answer a question, do not regularly go to a man with the assumption of getting the correct answer.
7. Offer hands-on experience and spend time teaching the basics to reduce anxiety throughout.

8. Explain the relevance of labs, assignments and lecture material to other areas or disciplines.
9. Discuss issues involving the ethics of computing.
10. Emphasize the positive social benefits of computing.

Not bad for a start, but clearly there is more work to be done.

The suggestions as laid out may seem obvious and even insulting to some professors today because they address a serious lack of respect for female students by faculty. The first six suggestions listed are not ground-breaking ideas but should instead be practiced by every teacher for all of their students. The type of behavior they suggest to modify, unless rampant only in the computer science department, should affect all female students in any program. While certainly important for effective and fair teaching, these suggestions do not address computer science specifically.

The remaining four suggestions address issues directly facing women in computer science. Teaching the basics thoroughly will help the women with less computer background than men by allowing them close the experience gap. Discussing the relevance of assignments and the social benefits to computing would help align the program more towards women's attitudes about computing. The discussion of computer ethics in the classroom setting is an interdisciplinary aspect of computing to which many women would probably respond positively. However, these suggestions are simply small adjustments to an otherwise rigid, male-dominated curriculum. These two cases present a set of possible actions to help increase women in computer science and together begin to suggest a comprehensive plan of action.

Women in Physics

Like computer science, undergraduate physics is dominated by men. Only 19% of the undergraduate degrees in physics in 2000 that granted to women (Ivie & Stowe, 2000). A study was conducted in 2003 which examined why few women were pursuing and completing degrees in undergraduate physics (Whitten, 2003). It was a broad study that examined nine colleges and their physics departments. Some of the schools examined were successful in terms of gender equity, while others were significantly under the national average (Whitten, 2003). The research aimed to determine the overriding factors that determined a program's success or failure to attract and retain women.

The study determined that successful programs had no single component that determined the success of women in physics. Instead there were a large number of many small, incremental actions that help to attract and retain women in the programs. Apart each amounted to very little, but in concert they created a powerful effect. The researchers used weaving fabric on a loom as a metaphor to describe this quality. The metaphor had three main components: The loom itself is the institutional support structure, the warp is support from the faculty and teachers, and the weft is the students who create an inclusive, female-friendly department culture. They concluded, "There is no switch that can be flipped to transform a department. Instead, there are many small incremental changes that weave together to make a sturdy and inclusive fabric" (Whitten, 2003). This idea of full participation by faculty, staff and students to help change a program's direction can also be applied to computer science.

Carnegie Mellon

The most comprehensive and successful study conducted to address the issue of women in computer science was conducted over a four-year span at Carnegie Mellon University by Jane Margolis and Allan Fisher. This project was unique in that Carnegie-Mellon actively incorporated the findings and suggestions as the study went on and saw tremendous results in both admissions and retention of female students. When the project began in 1995, only 7% of the computer science undergraduates in the program were women and only 45% of those were still enrolled after two years in the program (Margolis, 2003). Over the four year study students were periodically interviewed about their experiences in computer science to try to discover what factors were dissuading them from staying in the program. The results led to a plan of action that raised the percentage of enrolled women to 42% in 2000 and doubled the retention of women to match that of the men in the program (Margolis, 2003).

Margolis and Fisher determined that a combination of factors were primarily responsible for the lack of women in the computer science department. First, they identified that women came into the program with less experience than men. They also had a different attitude towards computing. The culture they encountered at Carnegie Mellon was one of "programming Gods" where ideal student spent all of his time programming, talking about programming, or thinking about programming (Margolis, 2003). This culture was also very masculine. Teachers used violent examples, assignments were detached and programming focused, and little was explored outside of computer science (Margolis, 2003).

The combination of the experience gap, difference in interest, and the computer science culture severely affected the self-confidence of the women in the program. In the first semester many women were highly confident and sure they could succeed. However, by the fourth semester doubt and worry were the major themes expressed in interviews. This change was reflected in the high rate of dropouts after the second year (Margolis, 2003). The culture of the computer science program, meant to produce superior students, actually unnecessarily harmed the women in the program. To combat this, Margolis and Fisher developed and implemented a comprehensive plan.

The impressive results they achieved came from eight distinct areas of improvement that were implemented by Carnegie Mellon over four years. Much like the loom described by Whitten, this multi-angle approach involved faculty, staff and students with many small changes that significantly improved women's experience in the program. Two of these interventions were deemed unsuccessful: having female staff write letters to and call top ranked female applicants and establishing a community of undergraduate women students. The effects of these attempts were minimal at best. There was little response to the directed recruiting by potential students. The community formed never reached a critical mass to continue on its own power. It is possible that these approaches would be successful if approached in a different manner (Margolis, 2003). The remaining six areas each had a noticeable, positive impact.

The six focus areas that were found to be effective were the experience gap, admissions, attention to good teaching, contextualizing computer science, culture, and outreach to high school.

The experience gap between men and women in the computer science program was addressed by providing incoming students four ways to enter the program based on prior experience. Depending on experience level, students with could take an additional introductory class which would not put them behind for graduation. This helped increase the satisfaction of both experienced and inexperienced students by giving them courses more suited to their backgrounds. It was also discovered that courses meant to be intense to "weed out" students, if given early in the academic career, forced many more women from the program than men. Moving these courses later in the academic schedule reduced this effect by giving the women time to gain the required experience and confidence to succeed (Margolis, 2003).

Admission standards also took into consideration the difference in experience level between men and women. Observations showed that prior experience did not predict academic success, so admissions requirements were altered to not give strong preference to students with high levels of experience. Combined with communicating to prospective students that experience was not a significant factor, this led to immediate gains in recruiting women into the computer science program from 1996 through 1998 (Margolis, 2003).

The next two areas, attention to good teaching and contextualizing computer science, deal directly with how computer science courses are taught. To improve teaching, faculty course assignments were altered so that the better, more experienced teachers taught the earliest courses. Women responded positively to having accessible, experienced teachers who could more effectively interact with the students early in their academic careers. Teaching assistants were trained and educated about the unique challenges facing women in computer science so that they would be more understanding of the problem and more capable of providing effective teaching to them.

Adding context to computer science courses helped women's attitude about computer science as a whole. Carnegie Mellon's approach included altering teaching styles and giving assignments that focused on truly interdisciplinary problems. One class in particular integrated the entire enrollment into a single software development team. This team required managers, technical writers, and marketing directors as well as developers and coders. Including non-computer science components to technical projects allows women (and men) to explore their full range of talents, both increasing their interest in computer science and helping them to expand their horizons beyond the purely technical aspects of computer science.

Culture was a difficult issue to face. The researchers found that the prevalent attitude was that the ideal student was a "boy hacker" who spent all his time in front of a computer programming. Free time was spent programming or playing computer games. Men and women both held this as the image of the ideal student. Technical knowledge was paramount, and those with less experience were teased and made fun of (Margolis, 2003). This culture was strengthened by the expectations of faculty of the students and pervasive within the department.

To combat the prevailing culture, Carnegie Mellon educated the computer science professors about the prevalence and dangerous effects of this stereotype. The professors then presented students with the idea that success in computer science is multidimensional and that the "ideal" student did more than just program. This approach had a clear impact on the teaching faculty who taught incoming students, who responded very well to the changes they were asked to make. Unfortunately, it had less effect on the tenured and tenure-track faculty who taught higher level courses (Margolis, 2003).

The outreach program was initially intended to benefit high schools, not Carnegie Mellon. It was to raise interest and improve the education of computer science for the high school students. An unexpected but pleasant result of the outreach program was that schools who worked with Carnegie Mellon were more likely to send students to Carnegie Mellon for their undergraduate education in computer science (Margolis, 2003). Maintaining these relationships would provide continuing mutual benefit for the high schools and Carnegie Mellon.

Margolis and Allan did note that not all colleges have the same environment as Carnegie Mellon. The main advantage it has over most other institutions was highly competitive admissions. The ability to alter admission criteria and class structure with no discernable difference in program quality is an advantage that not all schools possess. However, the results at Carnegie Mellon can still be useful for other colleges who take the time to study their own situation and apply the results according to their own circumstances.

Gokhale and Stier conducted a study in 2004 on the effects of curriculum only on female students in a technical department of a different 4-year university. They surveyed current female students and alumni to identify curricular and instructional traits that attract and retain women. Their findings re-iterated many of those that Margolis and Fisher found, "that a curriculum that places technology in the context of its real-world uses and impact is appealing to female students" (Gokhale, 2004). They conclude that it would benefit female students if instruction began with the consideration that many female students may not have the technical background of the male students. Not all schools may be able to implement all the changes or have such dramatic results, but even modest improvement can be a crucial first step to gender equity in computing.

Structure, Style and Attraction

These case studies all focused on the same general problem: a lack of women in technical fields. The agreement between them is that there is no single overriding factor that is hampering the success of women in their respective fields. The more in-depth studies all recommend a multi-angled approach to help increase the number of women in computer science. Margolis and Fisher discuss a complex plan with six distinct areas of focus to help women in computer science that was highly successful. Computer science departments looking to improve themselves by attracting and retaining more women should use these strategies after tailoring them to their own programs.

The strategies can be classified into three major categories: structure, style, and attraction. Structure is curriculum changes within the departments. These include restructuring course order, avoiding so-called "weed out" classes early in the academic career, and adding interdisciplinary classes to graduation requirements. These classes might explore more aspects of the field such as ethical ramifications or legal issues. Altering the structure of the curriculum in these ways will help women by better aligning the course progression with their attitudes about computer science and help reduce the strain caused by the experience gap.

Style deals with changes in how classes are actually taught. These include respecting women in the classroom by giving them the same attention and time as men, discussing ethical and social ramifications of theories and projects, and discussion of real-world repercussions of information technology. It may also include group projects that require interdisciplinary talents for success such as the class offered at Carnegie Mellon. These stylistic changes will help women's self confidence by allowing them success that is not completely dependent on their programming skills. They would also help combat the stereotype of the male computer geek as ideal student.

Attraction is characterized by changes to admissions and recruitment into the programs. These include establishing outreach programs to high schools, advertising programs in ways to attract more women, and altering admission guidelines to not unfairly reject women based on a lack of computer experience. These types of changes help account for pre-college factors that dissuade women from entering computer science.

Changing the structure, style, and attraction of a computer science department is necessary to help bridge the gender divide. Structure is critical to help address the problems once women enter the program, but is ineffective if teaching style is not altered to match. Style cannot account for women entering the program and the types of classes they can choose to take. Attraction alone may bring in more women, but they will still have to face adversity and change majors as they do now. All three of these must be implemented to some degree for a plan of action to be effective.

Altering the structure, style, and attraction of a computer science program has been shown by Margolis and Allen to help bridge the experience gap, increase self-confidence and align with the attitudes of female college students to help them succeed in computer science. The dramatic increase in enrollment and retention of women in the computer science department at Carnegie Mellon is direct evidence of this. While the sources of the problem are varied and affect women throughout their lives, there is now overwhelming evidence that colleges can make changes to help minimize these problems and significantly help women in computer science.

CHAPTER 4 – SECURING THE PIPELINE

An information security curriculum can be adapted to meet the style, structure and attraction changes suggested by current research. This would help draw more women into computer science programs and help keep them there while actually improving overall program quality. In addition to the benefits from drawing more women into computer science in general, increasing the number of computer science graduates with information security experience will help meet growing demand for security professionals. Every program will have different requirements and needs. In this chapter I provide an example curriculum that meets the structure, style and attraction recommendations suggested by current research.

Benefits of Information Security

Information security can be effectively used by an educational organization to increase the number of female students in computer science better than computer science alone. Many of the suggestions to help attract and retain women made by researchers can be implemented by adding an information security aspect to an existing computer science program. This is because information security is a far-reaching discipline that goes beyond programming and algorithms. While its roots are firmly planted in the core computer science subjects, information security branches out to a wide array of topics such as social engineering, computer ethics, and cyberlaw. It is invaluable that an information security professional be able to relate his or her knowledge to the real world and complex social situations. The inherent nature of information security is interdisciplinary. This is the key to why it is such a good starting point to create a computer science program in which women as well as men would thrive.

It is vital that U.S. colleges produce more graduates with knowledge of information security. Studies show that demand for security professionals is outpacing even that of IT professionals in general (Foote, 2001). Worldwide demand for information security was estimated at $8 billion in 2001 and is forecast by IDC to grow to $23 billion by 2006. This demand is fueled by several factors. One is an overall increase in security consciousness in the United States. Another is the emergence of Federal legislation mandating computer security standards such as The Gramm Leach Bliley Act of 1999, the Health Insurance Portability and Accountability Act of 1996, and the Sarbanes-Oxley act of 2002. All of these place requirements on different segments of private industry that will increase spending on information security and create demand for security professionals. If colleges do not step forth and provide enough qualified graduates, industries such as banking and health care might suffer due to the increased requirements placed on them.

Example Information Security Curriculum

To meet the structure, style, and attraction recommendations that were successful for Margolis and Fisher, I detail a simple example of an information security curriculum for an undergraduate computer science program. This example is loosely based on a program offered by the Center for Education and Research in Information Assurance and Security (CERIAS) at Purdue University as of the 2004-2005 academic year. My recommendation is not meant to be comprehensive or an end-all solution for any college. It is just an illustration based on a successful, existing program and how it may be implemented so that it will help female computer science students. Course descriptions are also only recommendations to help illustrate some, but not necessarily all, of the options available.

The program at Purdue University on which this is based is an interdisciplinary Master's program in information assurance and security. It is offered through cooperation between the departments of computer science, philosophy, communication and the school of technology. Students are required to take four core courses in computer science, cryptography, ethics and law. They then choose among many possible courses, but are required to have taken classes from at least three different programs by graduation (CERIAS, 2004). Although it was not necessarily designed with women in mind, the structure of this program is well suited to female computer science students.

The example curriculum is a four-course minor or focus for a computer science student. There would be two core and two elective classes; the core classes would be required while the electives could be chosen individually by students based on their own preference. This minor could by expanded to a major by adding additional and higher-level courses. It also may apply to programs other than computer science, such as computer technology.

Core Classes

Information Security and Computer Ethics would be required classes for all students seeking the minor/concentration. They may also be required for all computer science students if these suggestions are integrated into a computer science curriculum directly.

Information Security

The first required course of the security minor would be an introductory course in information security. This course would not require any programming experience but may require some basic knowledge of computers and computer networking. Topics it would cover might include, in no particular order, viruses and virus detection, software vulnerabilities and patches, operating system security models (file permissions, suid executions), basic network security, security primitives, and an introduction to cryptography and cryptographic applications. Depending on where in the overall CS curriculum this class is placed, the depth of the mentioned topics may easily be altered to accommodate the knowledge of the students taking the class.

Computer Ethics

The second required course would be a class on computer ethics. This class would include a basic introduction to ethics from a philosophical standpoint, but would focus on how ethics affects computing and careers in computer science. Topics for this course would include ethical programming, ethics in the workplace, white, grey, and black hat hackers, and more current topics on computer ethics.

Elective Classes

Students would select two out of these four classes by their personal preference. The elective courses are Cryptography, Cyberlaw, Advanced Information Security, and Risk Management. More advanced versions of these courses may also be available as further electives if the program were a complete major or expanded by a department.

Cryptography

This is an introductory course on cryptography. This course would focus on cryptographic principles and functions such as hashes, one and two-key systems, RSA, and digital signatures. The course would be more math-oriented than the introduction course and delve deeper into the science of cryptography but still focus on the use and implementation of cryptography for a security professional.

Cyberlaw

A course of legal issues for computer science professionals would be available to students in the program. It would include material on current and historic legal cases involving computers and computer security and an overview of current requirements to business such as HIPAA and Sarbanes-Oxley. This course may be taught by a member of a political science program.

Advanced Information Security

The sequel to Information Security, this class would go into more detailed analysis of many topics covered in the introductory course. It would possibly include network security, security modeling, protocol analysis, and other more technical security issues. Programming would be a much larger component of this course.

Risk Management

This class would introduce students to the concept of risk management. It would cover topics such as policy development and analysis, methods of policy enforcement, penetration testing, security audits, and other business-oriented security analysis topics. It would also cover methods of communicating these results to non-technical people. This material is well suited to be taught as a business course.

Addressing Structure

Once these or similar classes are available for computer science credit, they must be integrated into the curriculum in such a way that they will benefit women. Assuming no other major alterations to the standard computer science requirements, such as those recommended by Margolis and Fisher, these security courses need to be made available to students early in the academic career. One of the major problems women face in computer science is that they have less experience with computers than men. Providing challenging courses that do not require deep knowledge of programming will help women overcome their lack of experience.

There is no predetermined course order for this program and there are no prerequisites among the recommended courses, except advanced computer security. This allows for tremendous flexibility in scheduling. Students who choose information security should be encouraged to take at least one course per semester, but which class they take is up to them. The computer science program would have to ensure that by taking these classes, students would not fall behind others in the program.

Students with less computing background should be advised to take Computer Ethics and Cyberlaw during their first year, then Computer security and Risk Management in the next. This would help students ease into computer science by giving them important classes that will not "weed them out" if they lack programming skills. Students of a more technical background could take the security and ethics course in the first year, and Cryptography and Cyberlaw in the second. Students may also opt to take these classes later in their academic careers if they decide to focus on information security.

This flexibility will satisfy most students. Care must be taken, however, that guidance counselors and faculty take the non-technical classes seriously; they are as much a key of the curriculum as computer security and cryptography. It would defeat the purpose of having these classes if they are considered "blow off" or easy classes. Each course must be taught at a level that will challenge students regardless of technical or non-technical content.

By providing access to classes that require interdisciplinary skills, not only programming skills, women will feel more comfortable and confident in their studies. Doing well and being rewarded for success are major factors for confidence (Ambrose, 1998). Success will be determined by talent and effort, not experience. If women can have a positive experience where the men in their class are seen as equals, that can carry through the entire academic career.

Changes in structure must come when they have a chance to positively affect women. Advanced information security courses would have little bearing on the retention of female students. Most women change majors before the junior year of college (Margolis, 2003). The classes detailed here would make excellent first and second-year choices. If the goal of the department is to establish a full major in information security, more advanced classes would be introduced for junior and senior-level students. However, these would most likely have a smaller affect on retaining women in the program.

Addressing Style

If the classes are taught like traditional computer science courses, the structural changes will have a minimal effect for women. Although the courses in this minor cover topics outside the normal scope of computer science, they could still be taught in a way that discourages women. As discussed previously, women have a different attitude about computers than men. Classes that place computers within a social framework and focus on the real-world uses of technology are more interesting to women in general. The Computer Ethics, Cyberlaw, and Risk Management classes are excellent examples of courses that accomplish this task.

The Computer Ethics class would be taught from a philosophy perspective. It should focus on writing, discussion of ethical dilemmas, and other non-technical projects such as debates. Incorporation of presentations by successful professionals that can participate in ethical discussions with students would also be helpful while not relying on a heavy computer background. The style of this class would be to engage students in meaningful, insightful discussion to help them grow ethically. A strong ethical framework is important for information security professionals.

If an institution decides to teach students sensitive information, like how to create and combat computer viruses, they must also ensure that their students are educated as to the ethical ramifications of their actions. Security professionals are put in places of power because of their knowledge and access. As computers are used to store more and more information, the potential for abuse of that information grows. Other professions that place people in positions of power, such as law enforcement, have strict moral guidelines that they apply at all times. The ethics component of the security education helps to fulfill this requirement, but should not be the only time ethics are discussed. Ethics should have a place in every course where to help students build their own moral framework.

The Cyberlaw course covers current laws and regulations that deal with information systems. This is another non-technical class that requires knowledge of how technology fits in with the real world. As a security professional, one should know what legal responsibilities that an organization has to fulfill. This class should be taught from a political science perspective because it deals with international law and the civil repercussions of state and federal regulations. It should require students to complete research, write papers, and make presentations to the class.

Risk Management is another non-traditional computer science class to be included in the program. Because perfect security is all but impossible, the goal of security programs is to minimize the risk present to an organization. The process of risk management is designed to help keep the risk to a minimum. It includes risk analysis, penetration testing, system and policy examination, and then using this data to create a meaningful report. This class would require teams to work together to complete a risk analysis, either fictional or of a volunteer organization. It would give the students a chance to apply their computer knowledge to the real world while relying heavily on communication and analysis skills. The class would focus on students engaging with each other and their "clients" for whom they conduct a risk analysis.

These three classes are able to address the finding of Margolis and Fisher for the matter of style. They help female students develop and maintain a positive attitude about computers by discussing the ethical and social issues and real-world repercussions of computer science. They require interdisciplinary skills to be successful instead of just technical ability. Because of this, these classes may be challenging without unfairly punishing the women who take them. This style of teaching will also bring benefit to male students in the program. While programming ability is important for a computer science student, strong communication skills and interdisciplinary knowledge will only help a person in his or her career. These classes will not only help women get a better education, but can improve the overall quality of the computer science program itself.

Addressing Attraction

Without attracting more women into computer science programs, the structural and style changes within them will still be limited by the small number of women who are admitted to them. In order to attract more women into this augmented program, the changes must be advertised and championed within the program. The information security program is very different from the standard computer science curriculum and this fact must be communicated to both incoming students and the faculty and staff within the department. Here a school has a chance to do what it does best: educate people.

The focus of the education should be on high school outreach programs, advertisement on college websites, and education of admission staff. Educational material brought to target high schools should include information about the program. Recipients at these schools must be informed about the purpose and structure of the program so that they can answer potential student questions. The website for the program needs to have easily accessible information as many students, especially computer science students, use the World Wide Web extensively. The information should include a description of the program, the classes, and the approach taken within the classes. It needs to be highly accessible, well-presented, and up-to-date.

The program must also be championed within the department itself. One major threat to this type of effort is that the changes it tries to make are ignored or rejected by existing personnel. The worst enemy to change is apathy. The information security curriculum may encounter resistance from professors who feel that it is not real computer science, or who do not believe that the lack of women in computer science is a real problem. That is why someone must be designated to advertise and educate within the program itself. This champion must make sure that faculty understand the purpose of the changes and respect the additional, non-traditional classes. The more successful the champion is, the more the change will become a part of the program, and the more positive effect the changes will be able to have.

In addition to advertisement, programs should also adjust their admission requirements to account for the difference in experience level between young men and women. As it was shown at Carnegie Mellon, academic success is not determined by prior computer experience (Margolis, 2003). This is especially true for the information security program. Prior computer experience would not necessarily give a student an advantage over others because the curriculum requires a larger skill set for academic success. Altering admission requirements would reflect the skills and knowledge needed for success in the program, not just make changes that will bring in more women.

Conclusion

The lack of women in computer science is a serious problem that must be addressed by the academic community. If conditions do not improve, there will continue to be negative ramifications for women, academic institutions and the economy for years to come. As the information economy is further developed, more women will be left behind if they do not receive the same education as men. The unmet demand for computer science professors will continue to grow and the U.S. educational system will face a shortage of qualified people to teach the next generation. This could lead to considerable losses and a brain-drain for the United States as more and more research moves overseas. The economy will suffer because not enough qualified information technology and security personnel are being educated today, so these demands will be met by overseas firms. Raising admission and graduation numbers for women to match that of men would go a long way to addressing these serious issues facing the United States today.

There are many factors that contribute to the low numbers of women in computer science. The constant social pressure which shapes gender also shapes interests, attitudes, and the way we work and play. From childhood through adulthood, women receive messages that differentiate them from men. The end result of this for college students is that women end up with less computing experience and a different attitude about computers than men do. The culture that exists in many computer science programs causes undue pressure on women and slowly erodes their self confidence to the point that many end up dropping out of computer science entirely.

Many colleges have taken steps to address the gender gap in their own programs. Among these was a highly successful research project conducted at Carnegie Mellon by Margolis and Fisher. Over the course of four years these researchers interviewed students in the computer science program and recommended changes to be made to help recruit and retain female students. These recommendations had a significant positive impact on the number of female students in the program. Although a number of recommendations were made, they can be grouped into three general areas of improvement: structure, style, and attraction.

The nature of these recommendations makes them easy to implement in an information security program. The interdisciplinary aspect of information security is well suited to adapting to the style of teaching that was successful at Carnegie Mellon. Student presentations, group projects, and material that require knowledge outside of the realm of computer science all help expand students' knowledge while not punishing those with less computer experience. This is key to helping women be as successful as men in computer science.

Structure and style can also be addressed through an information security program. Students with different backgrounds can choose the courses that interest them because there are no prerequisites for most of the courses in the example curriculum. The loose structure provides for flexibility and gives time to students with less computer experience to build confidence and gain knowledge. Once this is advertised to students and within the program itself, it will become more attractive to women and more applications will be submitted. Admission requirements must be altered to account for the change in skills required for the program so that students with less computer experience are not unfairly kept out of the program.

The computer science community is facing two distinct challenges: bringing more women into the field and training enough information security professionals. Although the reasons why so few women enter computer science are complex, it has been shown that colleges can make great strides in increasing the enrollment and graduation of women. A well designed approach when creating information and computer security programs can help draw more women into computer science. Using an approach similar to the one given should help increase the participation of women in the future of information security and help to overcome both of these challenges.

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