Women in Computer Science: Problems and Solutions Through Technology

by

Abby Knickerbocker

Submitted to the Department of Electrical Engineering and Computer Science
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Abstract

This thesis studies the under-representation of women in the field of computer science. Previously published studies on the topic of women in computer science are examined in detail; specific problems and recommended solutions covered in these works are summarized and reviewed in a comprehensive fashion. In addition, this thesis focuses on ways in which existing computer technology can be used in order to increase the number of women in the field, as well as to improve the situation for women already working or studying in the area. In particular, online communication and data clearinghouses are examined as means of improving support for women in computer science. Furthermore, the topics of virtual reality and artificial intelligence are analyzed in terms of their relation to women in the field of computer science.

Thesis Supervisor: Anne Foerst
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Contents

Chapter 1

Introduction

Women have historically been largely outnumbered within the field of computer science. The continued under-representation of women in the computing field is a serious issue facing our society. When a large portion of the population is continually discouraged from entering into a discipline such as computer science, the field as well as society as a whole will suffer. Women can provide considerable talent to such a rapidly advancing discipline, and the discouragement of women's participation in computer science will not allow for the field to attain its full potential.

Computer science is not just an academic field. The fruits of the computer science industry are an integral part of everyday life for all of society. However, due to the fact that women are a small minority of the field, the products of computer science that contribute to our daily life are predominately engineered by men. Women must be equally represented within the field of computer science in order for society's daily activities and interactions to be designed with both men and women in mind.

Notably, the environment that women computer scientists face is not exclusive to the field. Many of the issues that are discussed in this thesis are universal. The specific issues that women computer scientists face as well as their under-representation also exist in many other fields. However, this thesis focuses only on the field of computer science and the issues that women computer scientists must confront.

The problem within the computer science field regarding women is not merely the fact that there are so few numbers of women present. Additionally, the environment of the field itself is difficult for women who are already studying or working in computer science. Thus, the solution to these problems must be two-fold: women must be encouraged to enter the field, and the field itself must be altered in order to retain more women.

Computer technology itself can be a boon to increasing the number of women within the field of computer science. On-line communication, data collection and storage technologies, and enhanced security can be used to improve the environment of the computer science field. Thus computer technology itself can be a valuable tool for attracting women to computer science and encouraging them to remain within the field.

This thesis is organized as follows. Chapter 2 analyzes many of the problems that women computer scientists face, as discussed in previously published studies. Here, facts are presented on how and where women computer scientists are both marginalized and discriminated against within the field. Chapter 3 then covers recommended solutions that have been proposed in previous studies on the topic of women in computer science. These solutions represent standard recommendations on how the field itself must be altered in order to acknowledge the importance of women, stressing the education of men and computer science institutions on the issues that women must face. Chapter 4 then moves to a more interactive approach to increasing the number of women computer scientists, with an analysis of how computer technology can be used to attract women to the field. Additionally, it is covered how women themselves can use computer technology such as on-line communication in order to improve the computer science environment and increase the number of women within the field.

Chapter 2

Previous Studies — Problems

We will begin by summarizing and reviewing the major topics covered by previous studies written on the subject of women in computer science. In particular, this chapter provides an examination of the problems that lead to the continued under-representation of women in the field, as well as the problems that women computer scientists themselves must face.

2.1 Gender Differences

There are a number of differences between males and females that are considered to be gender-based; in particular, many of these differences lead to conflicts and problems for women in computer science. Previous studies published on the topic of women in computer science have focused on these gender differences for both young boys and girls, as well as for men and women in advanced areas of computer science. This thesis will approach the gender differences separately for the two age groups: before college, and college and beyond.

Throughout many disciplines, the reality of the gender-based differences between males and females as well as the scientific bases of the differences have been examined in detail (see [51, p. 45]). However, discussion of the factuality of these differences is beyond the scope of this thesis. It is assumed that what is discussed in previous papers on women in computer science is valid and relevant information, and this thesis will not doubt the existence nor the scientific basis of the gender differences raised therein.

2.1.1 Pre-College-Age Differences

A discussion of gender differences will begin with those affecting individuals up to and including the ages of secondary schooling. Girls and boys in this age group are still learning about many different career paths, and have most likely not yet begun a definite career in computer science. Therefore, these problems lead to the continued under-representation of women in the field, rather than represent problems facing women computer scientists.

Aggression

Many of the differences between males and females that are discussed in previous works are based on the notion that males are considered to be more aggressive than females. Among young individuals, it is thought that boys are more inclined to push others out of the way to get at the computers. Girls, on the other hand, are disinclined to speak up if they are not getting the resources that they need. This is often described quite expressively as, "boys have bigger elbows" [47, p. 4]. Regarding the computer science classroom, this notion can have a detrimental effect on the performance of young girls. That is, girls must have a lot more initiative and desire if they are going to compete with boys for access to computing resources. For example, one middle school teacher describes the situation of the boys over-running computer resources as follows:

> "The computers are always consumed by the boys who rush in, desperate to continue where they left off the day before... An occasional girl wanders in, but would practically need interference from the heavens to gain access to these monopolized computers" [32, p. 39].

The problem may even begin at a much younger age. Preschoolers, aged 3–5, when given access to computers in the classroom, react in a similar fashion. The young boys are more inclined to push their way in front of the computers, and preschool-aged girls are more inclined to sit back and accept interference from the boys.

> "Even in preschool, males dominate the school computers. In one preschool, the boys literally took over the computer, creating a computer club and refusing to let the girls either join the computer club or have access to the computer. When the teachers intervened and set up a time schedule for sharing computer access, the girls spent as much time on the computer as the boys... Apparently, girls can enjoy the computer and do like to use it, but not if they have to fight with boys in order to get a turn" [22, p. 3].

Apparently, young girls are just as inclined, and in fact tend to enjoy, using computers when given the chance and when they do not need to fight for that usage. This emphasizes the fact that the gender difference discussed here is not one of natural abilities with respect to computer skills. In fact, the difference is in the degree of aggression that boys and girls will use in order to have access to computer resources.

Outside Influences

Gender differences between young boys and girls that may affect their success in the subject of computers may stem from external influences as well. Boys and girls may not be inclined or disinclined to use computers inherently by gender, but they are influenced to lean in one direction or the other at young ages by a number of aspects of the society in which they are raised. For example, there is still a strong lack of educated parents on the subject of computers. Furthermore, children are enormously influenced by their parents on a daily basis, from birth onward. Many times, such encouragement from parents follows negative stereotypes in terms of girls and their relationship to computers. "We see stereotyping in the kinds of toys parents encourage their children to play with, and parents often assume that little boys should have more access to computers" [32, p. 45]. Many people attempt to defend parenting, claiming that parents have tried to get young girls to play with toys that are historically related to boys, but girls still want to play with dolls and other toys associated with young girls. However, it has been shown that "the difference in toys cannot be explained purely by the children's preferences — the expectations of parents and other gift givers play a major role" [60, p. 3]. Boys and girls are encouraged to play with certain toys and games, and the gender differences that associate boys with computers and steer girls away from them are strengthened at very young ages.

Furthermore, these influences that tend to push boys or girls towards certain toys at young ages can have a negative effect on how children will see themselves as computer users.

> "These biases are carrying over into the realm of computerized toys and games. These games are both based on traditionally male interests, such as war and sports, and are marketed towards boys... Girls' lesser usage of computer games could be a factor in their being less positively disposed toward computers and in their lack of interest in computer courses, particularly as students who have played computer games are more likely to do well in their first college computing course" [38, p. 457].

Another study directly questioned preschoolers in terms of which gender computers and computer games were more appropriate for. Sadly, yet as expected, these young children already felt that computers were more suited for boys than for girls.

> "Some young children believe computer games and computers are for boys. In one nursery school, Pratto asked girls and boys aged 3 to 5 to name the toys they played with. Both girls and boys reported that boys played with Atari; it was never mentioned as a game for girls. We returned to that school and asked 42 children whether they thought computers were for girls, and then we asked whether computers were for boys... Although the majority thought computers were for both genders, the boys were not as sure of this as were the girls (71% of the girls and 57% of the boys). Of the minority, more children thought computers were for boys only (14% of the boys and 11% of the girls) than thought computers were for girls only (7% of the boys and 4% of the girls)" [38, p. 456].

When young boys and girls are influenced by outside forces in our society to either use computers or to avoid them, this can have an effect on students' performance in computing courses, and ultimately lead to certain career decisions. If girls are discouraged from using computers at a young age, they are also ultimately being pushed away from aspiring to careers in computer science. As seen earlier in this section, these influences can have an effect on children as young as three years old. It is apparent that three-year-old children are already being steered towards certain career paths simply because of the encouragement or discouragement that they are receiving from the world around them. Furthermore, much of this encouragement is from uneducated people who are unaware of the implications of their influences on young, impressionable children. Young boys and girls will begin developing ideas about what are appropriate career choices for the different genders. "From an early age, girls and boys learn to think of most careers as being appropriate for either men or women but not both. This will influence not just their career choice but how they view males and females aspiring to 'inappropriate roles' " [59, p. 6]. A similar study questioned young children about career choices if their gender were reversed, and even at a remarkably young age, the children were already forming their own stereotypes. "Children 3 to 6 years of age were asked what they would do if they were of the other sex. Approximately 70 percent of the children replied with a job considered appropriate for the imagined sex" [71, p. 44]. Thus, children are being taught at a very young age that there are distinct differences in what they will aspire to simply based upon their gender.

Reactions to Success and Failure

It is discussed in a number of studies how girls and boys in elementary school through high school tend to process certain information differently. In particular, it is believed that boys and girls tend to react differently to success and failure in their studies; in general, girls tend to suffer more in the long run from these differing reactions in courses such as computer science.

> "At both primary and secondary level, boys generally attribute their failures to a lack of appropriate strategies, while girls attribute them to their own lack of competence or the difficulty of the task. Boys attribute the successes to their good strategies; girls attribute them to luck. This means that boys and girls are using the information provided by their successes and failures differently. Boys are using this information to modify their strategies and develop more appropriate ones, while girls are gaining little positive benefit from their success and a lowered self-image from their failures" [19, p. 58].

In addition, it is believed that girls and boys tend to learn material in a slightly different manner. Girls tend to model what they have previously learned when facing new problems and situations, while boys tend to construct new solutions from scratch based on what they have processed from previous solutions. Furthermore, these differences between boys and girls may have an effect on their performance in certain subjects.

> "Females use reproductive strategies, relying on memory whereas males use constructive strategies, more dependent on understanding. Females are less autonomous. They rely on others to assist when they experience difficulties, believing that experimenters, teachers, and others in authority have the information they can use. In contrast, males seek to find their own solutions. Females are more likely to retain the strategy initially adopted, whereas males are more likely to take risks and develop new strategies to cope with different types of problems. Females are less likely than males to go beyond the information given in the learning environment to learn why the rules work" [19, p. 58].

In terms of computer science courses, the differences mentioned above tend to give boys an advantage. Boys' learning processes and reactions to their performances follow the structure required by most computer science courses, whereas girls' learning processes tend to conflict with this structure. Girls tend to struggle more with their successes, and ultimately suffer from a lack of self-confidence, which will be further discussed in section 2.7.2.

> "These differences in attributional processes have implications for student attitudes and achievement. Males develop more positive attitudes, rating themselves as more skilled than do females with comparable levels of achievement. For males, computing achievement relates to computing experience whereas, for females, this relationship is minimal, as they fail to develop the strategies assumed in most computing courses" [19, p. 58].

Social Needs

In general, it is believed that boys and girls develop socially in a different manner. Boys tend to act more aggressively and individually, while girls tend to accomplish certain tasks better in groups. These differences can have an effect on performance within the computer science classroom.

> "Girls and boys have different social needs which affect their evaluation of computing experiences. Whereas boys enjoy working alone and tinkering with computers, most girls prefer activities involving social interaction. Many school computer rooms place the computers in lines and allocate one child to each computer, effectively reducing opportunities for social interaction and hence being less attractive to girls than boys" [47, p. 6].

The computer science classroom seems to be organized in such a fashion that boys will feel more comfortable and succeed more often. Girls will feel out of place, because the learning environment of the computer science classroom does not meet their needs. The uninviting environment of the computing classroom that results from this form of education will be further discussed in section 2.3.

2.1.2 Differences in College-Age and Beyond

Aggression

In the previous section, it was discussed how boys tend to be more aggressive than girls, and this aggression affords them more time in front of the computer. The higher level of aggression found in males tends to remain the same for individuals at the college level and beyond. One woman describes how, "often, while I was working on a task, a male graduate student would physically push me away from the machine and interrupt my work so that he could get at the machine. This didn't happen to the men in the group" [65, p. 8]. Furthermore, this aggression in men gives them other advantages within the computer science community. That is, "an aggressive discussion style is inappropriately viewed as a sign of competence. If a woman (or, for that matter, a man) does not discuss issues aggressively, then she (or he) is often viewed as less competent, and is not taken as seriously as a 'more visible' colleague" [65, p. 9]. Women tend to have different communication styles than men, and lack of aggressive speech; it is disappointing that these differences in men associate them with competence in terms of computing ability. Thus, women are being negatively judged simply due to their manner of speech. If women want to be acknowledged for the skills they possess, they apparently need to avoid the more quiet, less aggressive speech naturally associated with women. With regards to behavior, women are thus required to alter their actions if they want to succeed as computer scientists.

> "Aggression, competitiveness, and even some brashness are necessary for a graduate student, for example, who must compete with other students for equipment, funding, and attention from professors. One doesn't get far by politely waiting to be noticed or for other people to stop using the computer" [59, p. 17].

The Double-Bind

When lack of aggression in women is seen as incompetence and inadequacy, this may lead many to believe that women should act more like men in computer science environments. Women should behave more aggressively, act more competitively, and increase the level of self-confidence they portray. However, many women computer scientists are faced with a double-bind because of this idea. When women computer scientists act like women, they may be considered incompetent. However, when they act like men, they may be considered either fake or hostile. Many women have trouble portraying a "masculine" attitude as their own natural behavior; in fact, women's forced aggression tends to be viewed as "bitchy." "He is 'assertive'; she is 'aggressive' or 'hostile.' He 'lost his cool,' implying it was an aberration; she's 'emotional' or 'menopausal.' Thus, her behavior is devalued, even when it is the same as his" [55, p. 151]. Rather than being viewed positively when acting in a more masculine fashion, women tend to be viewed as "unfeminine," and may again be devalued. One woman says, "as a woman, drawing the line and standing firm has always made me feel like a bitch and, actually, I feel that people saw me as one, too" [69, p. 221]. Adopting an appropriate fashion of behavior is difficult for any woman in the field of computer science.

> "Some argue that women students would be best to adopt a 'masculine' style in order to achieve classroom credibility. Others point out that a woman who does so may be perceived as 'aggressive' rather than assertive because her way of talking and acting does not conform to 'feminine' expectations: what a female student says in a 'masculine' style may be rejected out-of-hand on that basis. Indeed, the same behaviors seen as 'forceful' in a man may be viewed negatively — perhaps even as 'hostile' — when used by a woman... If a woman appears quiet and feminine, her success may be hindered because she is not competitive. If she does not appear quiet or feminine, she is socially ostracized. Women feel that there is no way for them to be accepted by their colleagues" [65, p. 12].

The implication is that women must alter the way they act on an everyday basis in order to be accepted as competent computer scientists. However, they must also be careful about the magnitude with which they adjust their actions. They must attempt to act in a more "masculine" fashion, but they must also avoid going overboard. This double-bind is a very difficult situation for women computer scientists to deal with. One woman graduate student describes the double-bind as follows:

> "It surprises no woman to say that women are socialized differently than men in our cultures. What is surprising is the effect of that socialization when women take roles traditionally held only by men. The most significant role change centers [on] developing confidence and competence. Part of the process of hurdle jumping is not just the getting over, it is the form which one presents in doing it; for women there is a subtle, but remarkable difference; women in the everyday world are not supposed to appear very confident and competent" [58, p. 2].

Specific Actions

In addition, differences between men and women may emerge in specific actions that they make. For instance, a different reaction emerges when a man drops a class and when a woman drops the same class. That is, "It is common to see different reactions to men and women dropping a class. According to her, when a woman drops a class, people remark that the class must have been too difficult for her; when a man quits, people say he must not have found it interesting" [59, p. 15]. Again, the same action from a woman draws the reaction that she must be incompetent, whereas the man appears to be intellectually superior to others.

2.2 Stereotypes

Stereotyping of women in the field of computer science is a serious problem. The stereotypes that women are associated with relate to issues that are discussed in other areas of this thesis: women are less competent, too quiet, under-qualified, and not serious about their professional careers as computer scientists. These stereotypes cause many troubles for women in the field. Men, and sadly even some women, react on the basis of these stereotypes, with the result that women are treated poorly as computer scientists. Hence, women are treated as if they were invisible, they are frequently patronized, and their competence is often doubted. "Research studies include evidence indicating that existing gender bias and discrimination at every educational level are affecting women's ability to advance along career paths and could quietly be directing females away from the technological industry" [33, p. 41]. In addition, much of the stereotyping against women computer scientists results in what many studies call "subtle bias." Subtle biases are slight discriminatory acts that, when viewed by themselves, may not be obvious cases of harassment. These subtle biases tend to have worse effects on women in the field than outright prejudice, since in many cases, actions that offend women computer scientists are unintentional. These actions tend to "undermine women's professional identities by drawing attention away from their roles as professionals and focusing it on stereotypical roles for women" [65, p. 8].

2.2.1 Women as Invisible

When other individuals in the computer science community uphold the stereotypes that women are incompetent and not serious about their careers, women tend to become "invisible." Their work is taken less seriously than that of others, and they tend to be ignored in both discussions as well as when job and project opportunities become available. Women tend to be "overlooked in technical discussions and excluded from group efforts, their work is attributed to male colleagues, and their opinions are not sought on relevant technical subjects" [65, p. 9].

The invisibility of women in the field of computer science is a very serious and negative result of stereotypes against women. These stereotypes include women not taking their professional careers seriously as will be discussed in section 2.5, women being less aggressive than men as discussed in section 2.1.2, and the frequent questioning of women's capabilities, as will be discussed in section 2.2.3. When it is assumed that women are not taking their careers seriously, they will become invisible when job and project opportunities open up. That is, employers and managers will look for somebody who will be as productive as possible, and if they follow the stereotypes, women candidates will be overlooked under the assumption that they do not highly value their jobs. In addition, women will continue to be invisible within the computer science field if the stereotype of women as less aggressive is upheld. If it is assumed that women will not speak out as much, or push their way into a project or technical conversation, then women will be overlooked as computer scientists. Similarly, if others are constantly doubting the technical competence of women in computer science, they will be ignored as candidates for any position, since people will be assuming that others are more capable for the necessary technical tasks.

In one study, the idea of the invisibility of women computer scientists is summed up as follows: "women in educational or professional settings may be ignored, interrupted, not looked in the eye, or simply not consulted for professional opinions" [22, p. 4]. If women are associated with the stereotype of being too quiet and incompetent, they will be overlooked and ignored because men, by the nature of these stereotypes, will appear to be better suited for technical discussion, as well as better candidates for completing technical tasks.

2.2.2 Patronizing Women

Patronizing behavior against women computer scientists stems from the same stereotypes mentioned above: those of incompetence and lack of seriousness for their professional careers. Women are patronized in situations where they are given simple tasks when they are capable of much more, when others offer to complete their work for them, and when they are spoken to as if they have little or no knowledge of computer science. For example, one woman describes how, "all I have to do is ask one simple question and the people I work with try to take over my entire research problem and solve it for me. I think they're trying to be helpful, but it doesn't help me if I'm never allowed the chance to do my own project" [65, p. 9]. This patronizing behavior takes away from all of a woman's previous successes in the computer science field, and degrades her to the level of a beginner, or, much worse, an ignorant. Women are being denied the same opportunities to challenge themselves as men when they are patronized in this way.

> "Women, as well as men, need the opportunity to work on open-ended research projects on their own. They need this experience to develop the discipline necessary to focus on a research problem; the creativity to formulate alternative paths to pursue; the technical judgment to evaluate different alternatives and to choose the most appropriate ones to follow; and the technical skill, self-reliance, and perseverance to carry a task through to its completion. For a project to be a significant learning experience, it must be challenging. Because less is expected of them, women are relegated to straightforward, menial tasks more often than their male counterparts" [65, p. 10].

Again, the patronization of women computer scientists is described as follows: patronizing behavior includes " 'talking down' to women, taking over tasks they have started, or extravagantly praising their merest efforts" [22, p. 4].

When women are patronized in this manner, their previous efforts, successes, and accomplishments are being ignored. Holding women up to negative stereotypes robs them of their individuality as computer scientists. Furthermore, a woman may be uncomfortable when a simple question may result in others trying to complete her work for her. This may lead women to avoid approaching others for help, and they may begin to struggle more than their male counterparts. Interaction with others is a crucial part of a computer science profession, whether in industry or academia. Additionally, if women are constantly being patronized by being inundated with menial tasks and excessive appraisal, they will naturally begin doubting their own abilities.

2.2.3 Doubting Women's Competence

Some of the previously mentioned stereotypes against women imply that women in general do not make good engineers. "There are still people who believe, consciously or subconsciously, that women are incapable of being top scientists" [59, p. 1]. On the basis of negative stereotypes it may be assumed that women do not have the background, and they are simply not competent nor qualified to complete the required tasks. Even if women have climbed the ladder to advanced levels of academia or industry, they are still doubted. For example, among women who had succeeded as undergraduates and were pursuing a more advanced degree, "academically superior women, who had typically been at the top of their undergraduate classes, were shocked upon entering graduate school to find themselves marginalized and isolated" [31, p. 57]. Women at these levels are doubted both in terms of their talent as computer scientists, as well as the means by which they arrived at these advanced levels of the field. It is assumed that they arrived at these points for reasons other than the fact that they are qualified to be there as talented computer scientists.

> "Some female graduate students are told that they have poor backgrounds, although male graduate students with the same undergraduate background are not told that. Frequently heard comments like 'I really don't think the women students around here are as good as the men' do great damage to women's self-images. In an environment that is difficult for all students, such comments make it even harder for women to perform well. It is not possible to succeed as a researcher if one's technical judgment and expertise are not respected by others in the field. It is very difficult to achieve a level of expertise if, as a student, one's peers and advisors have low expectations for one's success" [65, p. 3].

Many times the stereotypes of women as being less competent than men is visible in more detail. Some individuals with higher authority within the computer science community believe that there are certain areas where women are consistently inferior to men, and thus would not fill the requirements of engineering positions.

> "Some research supervisors believe that women do not examine problems to a sufficient level of detail, do not exhibit independent thought, or cannot make substantial contributions to a technical discussion. Broad generalizations about women's qualifications and abilities lead to reluctance on

> the part of some supervisors to accept women in research groups or to give them critical tasks" [65, p. 11].

In cases such as these, individuals with authority denounce previous accomplishments by a woman computer scientist on the basis of the stereotype that women are incompetent in the field of computer science. In fact, a study was made to determine whether women with identical accomplishments as men were considered less competent than their male counterparts. As expected, the individuals with hiring authority based the applicants' level of competence for the job on gender alone.

> "Department chairs were asked to make hypothetical hiring decisions and to assign faculty rank on the basis of vita. For vitae with male names, chairs recommended the rank of associate professor; however, the identical vita with a female name merited only the rank of assistant professor" [54, p. 7].

Women with apparent qualifications and accomplishments are doubted on the basis of stereotypes that view women negatively within the field of computer science. Such doubt in the face of a woman struggling to succeed as a computer scientist must eventually take its toll on her self-confidence. It seems obvious that if a woman is constantly being told that she is there for reasons other than her abilities, than she too will begin to doubt those abilities.

> "Women are often told that they lack qualifications needed for research projects and consequently are not given the opportunity to prove themselves. In addition to restricting the opportunities available to female students, this frequent questioning by others of women's qualifications leads women to doubt their own qualifications. Self-doubt leads to lower self-confidence and makes women reluctant to take on challenging projects to prove that they really are capable" [65, p. 11].

Women constantly face this questioning of their capabilities throughout all levels of the computer science realm. Because of this, "most women applying to engineering schools have worked hard to overcome 'deficiencies' in their backgrounds and, by the time they enter graduate school, are as well prepared as male students to undertake research in computer science," and in many cases even better prepared [65, p. 11]. Systematic doubting of women's competence and preparation in the field is a result of negative stereotypes and leads to a struggle for women computer scientists that men in the same situation will not face.

2.2.4 Subtle Bias Against Women

Although there is apparent overt discrimination against women in the field of computer science, the subtle discrimination women face may be all the more damaging. A subtle bias is something that may not be meant as overtly hostile, but may have heavy underlying negative meaning. Subtle bias may be felt by a woman computer scientist on a day to day basis. As more and more of these actions build up, women will begin to question their abilities, and feel more and more uncomfortable within the computing environment. Actions that may be categorized as subtle biases against women in the field of computer science vary. Some of the more frequent actions have been defined as follows:

- "Women are interrupted more than men.
- Faculty members make eye contact with male students more often than with female students.
- Faculty members are more likely to know and use the names of their male students than of female students.
- Women are often asked fewer or easier questions than males" [60, p. 9].

A woman may not be initially deterred by a single subtle discriminatory bias. However, if she faces these biases on a day to day basis, her self confidence will begin to dwindle, and she may begin to question her place within the computer science community.

> "Singly, these behaviors probably have little effect. But when they occur again and again, they give a powerful message to women: they are not as worthwhile as men nor are they expected to participate fully in class, in college, or in life at large" [55, p. 149].

The most disturbing characteristic of these subtle biases is that they are, for the most part, unintentional. Individuals do not realize that their actions may be affecting a woman's belief that she is a capable computer scientist. Most people in these situations are again acting on the basis of stereotypes that question a woman's place in the computer science community.

> "For the most part, people are not consciously trying to discourage women from science and engineering. Instead, people's behavior is often subconsciously influenced by stereotypes that they may not even realize they have... While perhaps it is comforting to know that no conspiracy exists against female computer scientists, it also means that the problem is harder to fight. The negative influences are... varied and decentralized" [22, p. 4].

Many times, women computer scientists themselves do not realize that such subtle actions are based on negative stereotypes, and may not necessarily be a true reflection of their own individual capabilities. That is, when other people do not realize that they are being discriminatory, it is equally hard for a woman to realize that discrimination. A woman may then begin to doubt herself based upon these subtle biases she is experiencing against her.

> "Often, subtle behavior is not recognized as discriminatory, for two reasons. First, the actions often are not *intended* to be discriminatory; the people who convey biased attitudes toward women may be well-intentioned. Nevertheless, the *effect* of their behavior is to undermine the professional image of women held by their colleagues and the women themselves. Second, any particular incident might appear trivial when viewed by itself.

However, when women experience such incidents daily, the overall effect of the environment is much greater than the sum of the individual incidents... Because subtle discrimination is harder to recognize than overt discrimination, it sometimes does more damage. Constant exposure to negative comments diminishes a woman's self-esteem and leads her to believe that she cannot succeed" [65, p. 3].

2.3 The Uninviting Computing Environment

2.3.1 Masculine Environments

The field of computer science, whether it be in industry or academia, is predominantly male. As a result, women who work within the field find themselves in an environment that may suit men better. In fact, a number of individuals believe that the professional working environment of the computer science field was designed with men in mind. "How often is it that a male computing student works in an environment that is designed by females for females? Yet women in computing usually work in an environment designed by males without female input" [47, p. 7]. Women may find a masculine environment uninviting, and choose to spend as little time in the work place or computer lab as possible. On the other hand, men may feel more comfortable in such an environment, and spend extra time in it. One woman computer scientist states:

> "I have always taken the view that I spend an enormous portion of my waking life in my work environment and that therefore it should be pleasant for my own sake... I have never liked clinical, sterile computing places. I do want a clean environment ... true ... that is a necessity with computers but I also want an environment that is warm, colourful and lively. I see no reason why a woman should copy a man's impersonal approach to his work" [47, p. 7].

The actual computing environment is not the only area that may be designed more with men in mind rather than being designed for women or as a gender-neutral environment. Some people also believe that computing tools are designed in a manner that would better suit men.

> "Borg . . . says computers would look more like crystal balls — spherical and approachable from all sides — if women had designed them. 'When girls use computers, they gather around them in small groups and treat it like it's part of their discussion,' she said. 'Boys elbow each other out of the way. Suppose you brought this information to bear when you thought about what a kiosk was — something that a family walks up to, not something one person sits in front of.'
>
> In addition to developing designs for desktop computers and kiosks, Borg also plans to hold workshops to develop more women-friendly handheld computers, getting feedback from social scientists as well as engineers" [11].

Computing resources themselves may better suit men, as mentioned above. Computers by physical design offer individuals the ability to dominate the resources, and push others away. Since men of all ages tend to use aggression to get at computing resources as discussed in section 2.1.2, current computer designs may better suit men than women.

2.3.2 Chilly Climates

In almost every academic or industrial computing environment, women are outnumbered by men. When a woman is introduced into this predominantly male environment, she will feel out of place and perhaps even uncomfortable. In academia, simply because they are so outnumbered, "women administrators, faculty, and graduate students face a chillier professional climate than their male colleagues" [22, p. 5]. A similar trend follows within the professional realm of computer science.

> "The climate in industry may be perceived as less favorable to women for a number of reasons including recruitment and hiring practices, a corporate culture hostile to women, sexual harassment, lack of opportunities for career development and critical developmental assignments, failure to accommodate work-family issues, lack of mentoring, and lack of access to informal networks of communication" [31, p. 69].

In fact, even if women have proven that they have every right to be a working part of the computer science community, they will still tend to feel out of place in it. "A study of doctoral students in a world-class computer science department found that while male and female students exhibited comparable performance quality in their studies, the women students felt much less comfortable" [50, p. 49].

Women tend to feel out of place in such an environment where they are so outnumbered. If a woman is not comfortable in the computing environment, she will not choose to remain there any longer than necessary. "Unlike some of their male counterparts, women computing students rarely 'hang out' in the computer labs. It is very easy for the lab itself to become a sort of 'boys club' to which the females do not want to come" [47, p. 8]. Besides finding themselves within a predominantly male community, women face certain uncomfortable situations that have become a part of the computer science environment. These actions mostly include, "the display of nude pictures, discussing sex, telling dirty jokes, and expressing negative stereotypes of women in an attempt at humor" [59, p. 21].

Women computer scientists face such conditions on a daily basis. They must work in environments such as these where women are consciously demeaned. A woman computer scientist will feel uncomfortable when women in general are spoken of in such unprofessional terms.

> "Because computer workplaces are often overwhelmingly male, women find themselves in what sometimes feels like a locker room environment, having to put up with behavior they might find offensive, such as sexist or sexual humor and female pin-ups. Additionally, some men use sarcasm or

> insults to communicate more than women do, causing women to interpret the environment as hostile, even when no offense is meant" [59, p. 35].

For example, a woman computer scientist describes her uncomfortable reaction to finding herself in such a predominantly male computing environment:

> "At a conference in France, a male speaker, who was speaking about the importance of testing, showed an overhead slide of a naked woman with a caption of the sort — "Would you buy this product without testing it first?" There were only 2 or 3 women in the audience (of about 150), but I had fleeting feelings of having accidentally walked into a stag party and wondering if he had either not expected any women to be there or had discounted the importance of directing his remarks to the women in the audience" [59, p. 22].

2.3.3 Pornography

In many computing environments, inappropriate material involving women is displayed on computer screens as wallpaper, posted on office doors, and even used to "demonstrate the graphics capabilities" [32, p. 36] of computer systems. Pornography is demeaning to any woman, especially when she is trying to maintain a professional image. It is difficult for a woman to compete as an equal in the computer science environment when the other representation of women in the area is a display of women as sexual objects.

> "Obscenity is pervasive in our environment. Humor in laboratories often takes the form of sexist, demeaning jokes. By placing women in demeaning roles, these jokes make women acutely uncomfortable. By focusing attention on women as sex objects, obscene material makes it difficult for them to establish identities as professionals. Obscenity tends to keep women from becoming integrated into the community as colleagues and adds to the 'locker room atmosphere' " [65, p. 17].

Pornographic jokes or demeaning images of women in a professional or academic computing environment can be very offensive to women who are trying to maintain the fact that they are equals to men within the field. Any form of obscenity towards women simply increases the struggle that women in computer science must confront.

2.4 Social Conflicts

As a result of the fact that the computer science environment is so overwhelmingly male, women tend to feel out of place in this community. Being a member of this minority gives rise to a number of social conflicts for women within the area, whether it be as students in academia, or engineers in the industrial world. Again, all of these conflicts stem from the fact that women make up such a small percentage of computer scientists; it seems natural that women in this small of a minority would find themselves in awkward social situations. As a part of this minority, women suffer from the "fishbowl syndrome," and must struggle with a number of social conflicts, including:

- Women computer scientists are first seen as women, rather than professionals; men in the area frequently look for romantic involvement.
- For a number of reasons, women tend to miss out on informal interaction, a valuable part of any computer science career.
- Being part of a minority, women receive a lot of unwanted social attention.
- As a result of social conflicts, women tend to withdraw from the computer science community.

2.4.1 Missing Out on Informal Education

Besides the formal, professional side of the life of a computer science student or professional, there is also an informal component that is crucial to success within the field. For the most part, these informal elements comprise of social interactions with both peers and individuals of higher authority, such as professors or managers. However, there are a number of reasons why women tend to miss out on these informal social sessions. When they are deprived of these social interactions, women computer scientists are missing out on a very crucial part of their careers.

> "A large component of graduate education comes from informal interaction with colleagues. Informal settings such as luncheons and technical 'bull-sessions' provide relaxed atmospheres in which students can receive feedback on their progress from peers and supervisors, as well as valuable technical knowledge. Personal relationships among colleagues also foster the development of understanding and respect, which contribute to a student's self confidence and ability to work well in groups. Often, women feel that they cannot develop the social side of professional relationships because they run the risk of attracting romantic attention that will erode the relationship. They are more likely to miss important opportunities for feedback and exchange of technical ideas, because they are not as easily accepted in informal settings as male colleagues" [65, p. 3].

Many women within the computer science community realize that they are being deprived of such a crucial component of their professional lives. One graduate woman describes this situation: "because men always think that I'm coming on to them, I don't feel comfortable joining technical bull sessions. I feel as if I'm missing a valuable part of my graduate education" [65, p. 15]. When women computer scientists are aware that they are missing out on something that their male counterparts are benefiting from, they will begin to feel less prepared, and more uncomfortable within the environment.

In addition, men may avoid women or intentionally interact with them as little as possible in order to avoid awkward social situations with women in the computer science environment.

> "Women don't know how to react to a teaching assistant's invitation to dinner, for example. Because of this, some men bend over backwards to

> avoid anything that could alarm a woman or look bad. Unfortunately, this means that women miss out on informal interactions. A professor might have chummy discussions with his door shut with male students but be more serious and leave his door wide open with female students" [60, p. 1].

Once again, women are missing out on a valuable element of the computer science experience simply because they are women. Men may fear the implications of a social conflict, or may simply be uncomfortable around women within in a professional setting. Thus, women are left out of crucial professional situations, such as these informal bull sessions.

2.4.2 Always a Romantic Prospect

The previous section touched on the idea that women computer scientists may primarily be seen as potential dates. As one of very few members of the opposite sex in a predominantly male environment, women are first seen as romantic prospects rather than professional colleagues. Women are constantly inundated with romantic invitations from their male counterparts; this can be a very uncomfortable situation for a woman computer scientist who is trying to establish a positive professional image for herself. In addition, she is often put in situations where she must turn down romantic invitations from individuals who hold a higher level of authority. It is difficult for a woman computer scientist to turn down these invitations without the fear that it may ultimately have a negative affect on her career. Men do not often run into to this uncomfortable situation. Women computer scientists also feel that many of their everyday actions are wrongly interpreted as "come on's," when in fact they are giving no indication that they are romantically interested in a man.

> "Men's expectations of how a woman should behave frequently cause her actions to be misinterpreted. Women in this environment often feel that they are viewed primarily as potential dates. A female graduate student who is friendly with a male colleague runs the risk of having the male

colleague assume she is romantically interested in him. Other men may make this assumption, whether or not the man concerned does. A lunch appointment with a man to discuss a technical matter may be viewed by him and/or other members of the community as a social date" [65, p. 14].

When other individuals begin to make judgments about the romantic involvement of a woman computer scientist and one of her male colleagues, she runs the risk of being ostracized. Inter-office relationships sometimes lead to tension, and women can be put in this awkward situation by assumptions that other colleagues are making about her. Men may also begin to avoid women computer scientists in fear that others will assume that there is a romantic relationship between them. This inclination towards avoiding or ostracizing women computer scientists will be discussed in section 2.4.4.

2.4.3 Overwhelming Attention

Because there are so few women in the field of computer science, women tend to be treated differently from their male counterparts by the rest of the community. As part of a minority, women tend to receive much attention, whether it be romantic or otherwise. This attention can be a large nuisance, and can distract a woman from her professional duties.

> "Many of the men in the laboratories are unaccustomed to being around members of the opposite sex in professional contexts. This gives rise to differential treatment of women that can make it more difficult for them to work effectively. The imbalance harms both men and women. Women are inundated with social attention, creating an uncomfortable social atmosphere that interferes with their academic progress. Women must spend extra time and energy dealing with problems that arise from the social imbalance. Some women react by becoming wary of all new men they meet. Thus, some men are confronted with negative reactions from women to seemingly innocuous, friendly overtures. In addition, men

are frustrated by the lack of women with whom to interact socially" [65, p. 4].

Women are treated very differently from their male counterparts, and much of the attention that they receive is unwanted. Women may try to avoid men or imply that they do not enjoy the attention that they are receiving, but in many cases, those requests to be left alone are not granted to women computer scientists. "In an environment that is ninety percent male, the women are inundated with unwanted attention. Often a woman's response of 'no' is not taken seriously; she is repeatedly bothered by the same man or by others" [65, p. 16]. It is important to emphasize that this unwanted attention tends to put a woman in very uncomfortable situations. Furthermore, she must be careful so as not to offend anyone through her actions. In addition, these are struggles that men in the computer science community must seldom face.

2.4.4 Withdrawal and Isolation

As a result of difficult social situations that women computer scientists deal with, they often end up withdrawn from the rest of the community. This isolation tends to be the result of two separate and distinct situations. First of all, women may be avoided by men in the area, either because men are not used to interacting with women computer scientists, or because they fear the repercussions of a social interaction with a member of the opposite sex. On the other hand, women may intentionally withdraw themselves from the computer science environment. If a woman is uncomfortable with unwanted social attention or incessant romantic invitations, she may choose to isolate herself from other individuals in order to avoid this attention.

As mentioned, women may be isolated from the community because men are unprepared to deal with women in a professional context. Below, a professional woman gives her account of the isolation that she felt from men in the environment in which she was a member.

"I was. . . the first full-time woman faculty member in my department.

> There really was difficulty among my male colleagues in associating with a woman as a colleague. I think they literally did not know how to talk to me, and as a consequence often just did not talk to me. They would not invite me to have lunch with them, which was a very ordinary experience there... they would walk past my office and ask the next person and never asked me. [Years later] I asked one of my colleagues why this was so. And he said, 'You know what would happen if I asked you to lunch... People would talk' " [18, p. 36].

Here, a professional woman computer scientist suffered because of men who were uncomfortable dealing with women in a professional setting, and she was isolated from the rest of the professional community. In addition, she notes that men avoided her, and she became withdrawn because the men were worried about the image that they would be portraying by interacting with a woman computer scientist in a social context.

In addition, many women find themselves intentionally withdrawing from the computer science environment, because they become increasingly uncomfortable with the social attention that they are receiving.

> "One survival tactic that some women adopt in an unsupportive environment is withdrawal. They isolate themselves from their research groups and may select a research topic that requires little interaction with others. The environment encourages them to deprive themselves of the benefits of working with and learning from others — an integral part of graduate education" [65, p. 13].

One woman computer scientist describes how she feels uncomfortable with men in the professional setting. "I am uncomfortable about asking certain male graduate students for help (about the system, projects, etc.) because it might be viewed as 'coming on' to them. More times than not, the answer to a question is followed by an invitation to go out" [65, p. 15]. As a result of the discomfort that she feels regarding men in such awkward social situations, she will avoid asking for help the next time she needs it. This isolation is quite detrimental to a woman's success, and an issue that her male counterparts must rarely face.

2.5 Family Responsibility

Women in the field of computer science, whether they are students or working professionals, often find themselves struggling with both the duties of a mother and a scientist. Many more women with families than men in the same situation face this struggle, and may eventually end up leaving their profession. "Married women without children are more likely than married men without children to leave science and engineering employment, and women with children are more likely than men with children to leave science and engineering employment" [31, p. 66]. Even married women without children tend to leave the field more frequently than unmarried women or married men. Eventually, many more women in the field of computer science than men will end up leaving their positions in order to fully perform their non-professional responsibilities. Along the same lines, many more women within the field find it necessary to reduce their work to part time because of their duties in the home. Within the the entire area of science and engineering, "among recent bachelor's graduates, 29 percent of women but only 1 percent of the men who are not employed cited family responsibilities as the reason for not working" [31, p. 65]. Similarly, "twenty-one percent of doctoral women scientists and engineers with children under 18, but only 2 percent of comparable men, are employed part time" [31, p. 66]. Thus, performing both family as well as professional responsibilities is an issue that women computer scientists must face much more frequently than their male counterparts.

Balancing the demands of a family and a career for a woman in any field can be a great struggle. "While achieving such a balance may be difficult for people pursuing many different careers, there are certain aspects of a tenure-track position in a scientific field that render the balancing act particularly difficult" [30].

Women in computer science who are on track for tenure within the field struggle tremendously with the dual-responsibilities of a family life and a professorship. Most graduate students complete their Ph.D.'s in their middle to late 20's, and tenure is typically granted in the middle 30's. These years that require such large amounts of time and effort from a woman in order for her to be granted tenure intersect with a woman's child-bearing years. As a result, most women in the field feel that a choice must be made to have one or the other: either a family or a professorship. "Both rearing small children and achieving tenure are tremendously time-consuming efforts; doing both at the same time seems to be exceptionally difficult, if not impossible" [50, p. 53].

For these reasons, many women choose industry over academia, because they feel that industry can be more sympathetic regarding the demands of a family. One professional woman states:

> "The clear advantage of industry over academia is that it's often possible to work part-time for a finite period (say, a few years) and then return to full-time work without having totally destroyed one's career. That simply isn't true in academia, where the years one wants to work part-time often overlap with the very years in which one is working toward tenure" [32, p. 41].

Although it is more feasible for a woman to have a family while working in the computer science industry than to earn tenure in the field, industry also has its disadvantages.

> "Due to their primary responsibilities of rearing their children, these women have to become less aggressive and less competitive at work and simply settle for low-paying jobs having fixed hours and limited responsibilities ... Some women view their work as of secondary importance, with their husband's work having primary importance. Therefore, these women are unwilling to relocate or accept positions requiring long or irregular hours. Determined to succeed, a few women sacrifice having children and a family life in order to compete professionally" [33, p. 41].

Many women accept jobs in the computer science industry that require less than what their qualifications meet. Women may find themselves in this situation for two reasons. First, a woman may choose a specific job in a conscious effort to balance the responsibilities she may have at home. That is, a woman may know that she is professionally more capable than the job that she has accepted, but feels that she should dedicate more of her time and energy to her family life. The second reason for women working at jobs that require less than what they are capable of is far more disturbing. Employers and other individuals in the computer science industry may assume that although women choose to pursue a career, they are still not taking that career seriously. "So even if a woman chooses not to have children or not to take time out to raise them, employers will often assume otherwise and treat her accordingly" [60, p. 33]. Women are not given the same opportunities in industry as men are simply based on the fact that they are capable of bearing children and may eventually choose to do so. "Women are handicapped by doubts about the seriousness of their professional intentions" [65, p. 2]. In some cases, when employers interviewed prospective engineers, "only women were asked questions about marital status and dependent children" [35, p. 90]. Furthermore, most of these assumptions are based on the fact that women will miss a lot of work during the child-bearing and child-rearing years. However, this is not a very strong assumption; in fact, a military study showed that women actually took less time off than men, even after accounting for the time they took off for pregnancy (see [45]).

Another issue in industry regarding the responsibilities of a family life is that of proceeding up the managerial ladder. Many women are held back or not considered for managerial positions at all simply because they are women. Employers may assume that women will leave the company due to family responsibilities, and therefore may feel that promoting them to managerial positions may ultimately hinder the company. Again, the employers are assuming that women may be taking a short pregnancy leave at some point, or even choosing family life completely over their career, and leaving industry for any number of years. Managers and employers are judging women's individual priorities based on stereotypic myths, and may choose not to promote or even hire women because of these stereotypes.

2.6 Shortage of Mentors and Role Models

Mentors are a very important part of any computer scientist's education. They serve as guides, show younger computer scientists "the ropes," and help them sort out many of the details of becoming a computer scientist.

> "Mentors play a crucial, though usually informal, role in the training of young computer scientists. In general, a mentor shares with a less experienced colleague information about how to get research funding, avenues for publication, the informal power structure within a department and within the discipline as a whole, and so on. Mentors may invest a good deal of time in their junior colleagues and may offer them important opportunities for research collaboration" [50, p. 51].

Most women computer scientists prefer to have women mentors. Unfortunately, since there are so few women computer scientists at advanced levels, these needs cannot be met for most young women computer scientists. One study notes the lack of women role models for *all* engineering fields, not just that of computer science. "Few women and underrepresented minorities find role models in their science and engineering fields. Among full-time ranked faculty in these fields, women are only 16 percent" [31, p. 34]. In many cases, women computer scientists will look elsewhere in order to find women mentors to fill their needs. That is, "Not surprisingly, women seek out female faculty... One solution found by electrical engineering graduate students was to undertake research in industry, where they were often able to find women mentors" [32, p. 43].

It is apparent by the lack of women who can serve as mentors that most women computer scientists will receive mentoring from a man. Unfortunately, women computer scientists will not always benefit from male mentors. In fact, in many cases, the same male mentor will serve his male protégés better than his female protégés.

> "Despite the importance of having a mentor, there are few formal policies to ensure that every graduate student or junior faculty member receives mentoring. Although every graduate student, for example, has a thesis supervisor, the supervisor typically devotes different amounts of energy to different students. It is reported that 'women are more likely than men to be excluded form this sort of relationship with senior faculty'... As long as most of the people in positions of power are men, and as long as differences in sex are considered to be of great importance, junior men will benefit" [59, p. 30].

If young women computer scientists are not receiving the same level of mentoring as men, they will suffer as a result. Women will not receive the same information on such necessities as funding and research projects, and their self-confidence as computer scientists may be lowered as they begin to feel more out of place than their male counterparts.

In addition to mentors, women should also benefit from role models within the computer science community. It is important for a young woman computer scientist to have female role models to look up to, as well as to be reminded that becoming a successful computer scientist is not such a formidable prospect.

> "A role model can serve as evidence that a successful career in computer science is not only a possibility, but a normal and unremarkable option for women. The existence of role models *does* matter, and it matters to women at all stages of their careers. For students, female faculty members prove, by their very existence, that Ph.D. degrees and faculty slots can be attained by women" [50, p. 51].

Unfortunately, because of the low numbers of women in higher levels of the computer science field, female role models are difficult to find. Thus, many women struggle with the prospect of being a "sole fighter," which can be a very daunting and challenging experience.

2.7 Other Problems

2.7.1 Physical Safety

An issue that affects women computer scientists much more so than men is that of physical safety. The culture of computing, whether it be in terms of a computer science student or a computer science engineer working in industry, requires one to be in the laboratory or in the workplace after dark. Traveling alone from the laboratory to the dorm, or from the workplace to the car, is dangerous for a woman, especially when the university or the workplace is located in a high-crime area or an urban setting. The threat of physical safety is not as strong for men since crime rates are much higher for crimes against women than men. In addition, women are more likely to be injured than men if a crime is committed against them (see [23]).

If a woman believes that her place of work or computer lab is a serious threat to her safety, then a woman may be discouraged from staying in the computing environment as long as needed. One woman professor stated, "in many places it is a real problem to do work at night for security reasons, but it is a necessity for professional reasons" [43, p. 32]. Women may run into a conflict if they need to work, but staying in or traveling to the computing facilities is physically unsafe. Access to well-lit, short routes for women to travel on at night as well as safe entrances and facilities themselves are necessary for women in order to complete their work, but are not always available. "If working at night in the department or on public terminals is not feasible, a woman's working hours are restricted to a subset of those available to her male colleagues" [50, p. 48]. If something as basic as access to resources is not a standard for both men and women, women will not have the opportunity to perform at the same level as men.

2.7.2 Diminished Self-Esteem

In addition to the many other problems that women face as computer scientists, it has been shown that "the self-esteem of bright females actually tends to decline during college," [47, p. 5] a problem that their male counterparts do not tend to suffer from. Thus, women who are performing at the same level as men may seek out lower goals and accept lower pay. For instance, "when male and female college students were asked to predict their midterm test score before taking it, men had higher expectations for themselves than women did for themselves, even though the two groups actually performed the same" [26, p. 229]. Such a loss of self-esteem can lead to much self-doubt, lowered expectations, and in some cases, dropping out of the field of computer science altogether. In such a competitive field where women are highly under-represented in the first place, diminished self-esteem can be a very harrowing and challenging experience for a woman.

There have been many studies that discuss how women between the ages of 20–25 suffer from a loss of self-esteem. "One would expect these women to be among the most capable of computing graduates and yet their self-esteem and their confidence is considerably lower than that of their male counterparts" [47, p. 6]. In particular, most women in this range, when compared to men at the same level of performance, tend to doubt their abilities twice as often.

> "The women were indistinguishable from the men in objective measures of preparation, career aspirations, and performance in graduate school. They differed significantly in their perceptions of their preparation for graduate study, in the pressures and roadblocks that they experienced, and in the strategies that they developed for coping with these pressures... 30% of the women versus 15% of the men questioned their ability to handle the work; 27% versus 12% found criticism difficult to accept; only 30% of the women versus 57% of the men felt confident in speaking up in class; and 33% versus 9% feared that speaking up would reveal their inadequacies" [50, p. 50].

The problem of diminished self-esteem that many female computer science students must face tends to perpetuate the problems of the "impostor syndrome," where women tend to feel out of place and inadequate [42, p. 4]. Feelings of self-doubt and lack of confidence can only be magnified by feelings of diminished self-esteem. Women in computer science may then be inclined to feel more inferior and incompetent within the field, even though they are most likely as competent as their male counterparts.

In fact, a study of one introductory computer science course "found that at the beginning of the course men had higher expectations of success, greater confidence in their computing ability and frequently intended to study further units in computing, but there were in fact no significant gender differences in final academic results" [20, p. 208].

Although women show no lack of ability in terms of computer science skills when compared with men, they frequently tend to have lower expectations than their male counterparts. In fact, a number of studies note the fact that women's self-confidence may be directly related to others' expectations as a result of negative stereotypes. If women are under the assumption that others are comparing their performance to that of men simply based on their differing gender, women tend to perform worse.

> "Stereotype threat and disidentification with regard to women and mathematics through altering the instructions under which men and women took the *same* difficult test: 'Women performed worse than men when they were told that the test produced gender differences... but they performed equal to men when the test was presented as insensitive to gender differences' " [31, p. 37].

This example shows that women are directly aware of the fact that stereotypes do exist; in fact, women are negatively affected by the assumption that others are peering at them through these false stereotypic looking glasses. The lowered self-esteem that many women face as computer scientists may lead them to doubt their own abilities and ultimately choose to turn away from the field.

2.7.3 Gender-based Salary Gap

There is a general gap in salaries between men and women throughout the professional field of computer science, whether they be employed in the academic realm or the industrial realm. However, it is important to note that this discrepancy is not exclusive to the computer science field. In general, women have made less money than men throughout all disciplines. Much of this is due, however, to the fact that women tend to be employed within disciplines that offer less money in general, to both men and women.

> "Salaries are highest in mathematical/computer science and engineering, fields in which women are not highly represented. Salaries are lowest in fields in which women are prevalent, such as life sciences and social sciences" [31, p. 72].

Women are consistently paid less money than men for similar jobs throughout most fields. However, not all salary gaps can be explained by this fact. Women directly within the field of computer science make less money on average than men with the same qualifications and general area of employment. In 1992, women computer scientists with either a bachelor's or a master's degree earned $3,000 less than their male counterparts [31, p. 72]. The gender-based salary gap does not end there. In fact, it stretches over all areas of the field of computer science in which women are employed. For example:

> "In 1993, among employed science and engineering doctorate-holders who worked full-time, the average salary for women was $50,200 compared with $63,600 for men. The observed gender salary gap of $13,300 is quite substantial and corresponds to women's making only 79 percent of what men make" [31, p. 72].

Women computer scientists are earning a considerably smaller amount of money than men with the same qualifications. The trend is consistent throughout all ranks of the computer science field. In fact, "at the managerial level: for every dollar earned by white men, white women earned 74 cents; African American women earned 58 cents; Hispanic women earned 48 cents; and Asian/other earned 67 cents" [16].

If women are consistently being payed less than men within the field of computer science in a manner that can be explained by nothing other than their gender, women may become very discouraged. It is difficult to accept less money for a profession in which one should only be judged on the quality of his or her work, when it is apparent that women are being judged on much more than that. Coming to terms with the fact that she is not being fully appreciated for her technical competence simply because of her gender, a woman computer scientist may become very frustrated. Ultimately, women may choose not to enter into the field of computer science, where they will most likely be unfairly judged and compensated based on the fact that they are women.

2.7.4 Lack of Promotion

Women within the field of computer science are not only most likely to be payed less than their male counterparts, but they are also less likely to be promoted, both within the academic realm of computer science, and also within the professional realm. This lack of promotion and ascension up the professional ladder that is apparently based on gender can turn many women away from the computer science field. The apparent glass ceiling that exists in the computer science field can discourage many women from pursuing a computer science career, as well as encourage them to leave the field once they are in it.

Within the academic circle of computer science, women are less likely to be promoted from one degree of professorship to another. In 1997, the number of women in Ph.D. granting institutions who were full-time professors was 62, whereas 1044, or 94%, were men. Similarly, there were 100 associate professors who were women, compared to 848, or 90%, who were men. Only 101 women were assistant professors compared with 411, or 80% of men (see [49]). The percentage of women professors in the computer science field steadily shrinks moving further up the professional ranks.

The number of women in advanced positions within the computing industry is not any more promising. "Only 2 percent of the CEOs of technology companies in the United States are women, compared to 7.9 percent for all industries" [34]. Not only are women in such a huge minority at the top-most level in industry, but the trend continues all the way down the ladder. Women who hold positions at the managerial level are much more sparse than men with the same backgrounds. One study performed a survey of women within the upper ranks of large companies, and women cited a number of reasons that lead to an apparent glass ceiling.

> "What holds women back from top management? Women executives say:
>
> - Male stereotyping and preconceptions of women (52%)
> - Exclusion from informal networks of communication (49%)
> - Lack of significant general management/line experience (47%)" [15].

Most of these causes are discussed elsewhere in this thesis as issues that women computer scientists face. Stereotypes that are held against women is covered in section 2.2, and the lack of informal communication and interaction is further discussed in section 2.4.1.

In a manner similar to how women become very frustrated and discouraged by being forced to accept lower salaries than their male counterparts as discussed in section 2.7.3, women may respond accordingly when they realize that their chances of being promoted are generally lower than that of men. There is a great discrepancy in the way that individuals are moved up the professional ladder within the field of computer science. If women are consistently being promoted less than their male counterparts, such gender-based discrepancies may ultimately discourage women from pursuing careers in the computer science field.

Chapter 3

Previous Studies — Recommended Solutions

Chapter 2 of this thesis examined the problems that women in the field of computer science face as presented in previous studies. As well as addressing the problems that women computer scientists must deal with, many of these studies also introduced and examined possible solutions for these problems. In fact, a number of studies gave concrete examples of situations where recommended solutions do in fact successfully attain and retain women within the field of computer science. For example, "some colleges and universities do better at encouraging women... to enter — and stay — in undergraduate science and engineering programs than others. Helpful... are active support groups, encouraging professors, and peer and faculty mentors" [31, p. 35]. Such programs are merely a small number of the recommendations that have been previously proposed. This chapter discusses a number of the solutions as presented in previous studies on women in computer science.

3.1 Encouragement at an Early Age

In order to encourage more women to study and work in the field of computer science, many studies recommend reaching out to young girls who are still in high school or younger. By the time a student begins college, she has already chosen the field in which she hopes to remain for many years. If girls are not being encouraged, or even worse, being discouraged, to find interest in computer science, then fewer girls will choose to follow this career path. If young women are being encouraged while in secondary school or younger to enter into the computer science field, then more women may decide that computer science is an attractive and interesting field. Previously published studies recommend a number of different ways in which young girls can be encouraged to pursue computing at a young age.

3.1.1 Dispelling Common Myths

Many young girls have false beliefs about what it would be like to pursue a career in computer science. Women may be basing their career choices on these myths, and choose not to become computer scientists because of them. "It appears that the perceptions which are held by schoolgirls and undergraduates about careers in computing do not match the reality, and that many girls are deterred from a career that they would find rewarding and fulfilling" [20, p. 208]. If such false beliefs about careers in computer science are not dispelled of, then the field may be losing a great number of very talented women. Many studies in fact discuss how dispelling myths about computing would greatly increase the number of women in the field.

One study (see [20]) discussed how the goals of reaching out to young women should focus on eliminating any of the false beliefs that girls may have about the field and its working environment. If young girls begin to recognize the reality of the field of computer science, many more women may eventually decide that they would be interested in pursuing a career in the field. The study remarked that the goals of encouraging young girls should be:

- "dispelling the popular myth that computer people are antisocial, working alone at their computers and unable to communicate with other human beings, and
- of demonstrating that computing activities and careers are varied, challenging, interesting and people oriented.

> The next challenge is to dispel these myths and present a more accurate image within the school and university curricula" [20, p. 211].

Young girls should be well-informed about the reality of the computer science field. Only then may women make well-informed decisions about the appropriateness of a career in computer science for their own lives. If popular myths about the field are eliminated, then more women may choose to enter into a career in computer science.

3.1.2 Informing the General Public

A number of studies touched on the fact that girls are very strongly influenced by both their parents as well as other members of society that they come in contact with on a regular basis. If such individuals are falsely influencing girls about the field of computer science and its suitability in a young girl's life, then girls may be heavily discouraged from choosing to enter the field. Preventing this form of negative bias from affecting a young woman's career choice may greatly reduce the disparity in numbers of women within the field of computer science. To prohibit such false influences from discouraging women from enter into a career in computing, it is important that the general public be educated about the reality of the field. If parents and other individuals are aware that women can have extremely successful and satisfying careers in computer science, then they ultimately may not be heavily influencing young girls to choose a different path.

> "Alluding to studies indicating that a girl's potential depends to some extent on her mother's level of education, Clarke said we must address the more general education of the public through advertising and the media. Good will and a first-class curriculum cannot counter mothers who want to withdraw their children from classes or even schools if their daughters do poorly in computers" [32, p. 44].

It is important for all members of society to understand that girls can enjoy computers, and become successful engineers or academics within the field. Implying that such accomplishments are not possible or very improbable will only worsen the scarcity of women within the field of computer science. Educating the general public on these issues can help to lessen the existing disproportion of women within the field.

3.1.3 Actively Supporting Girls During Susceptible Ages

Previous studies on the subject of women in computer science cover the idea that girls are more susceptible to losing interest in the field between the ages of twelve and fifteen (see [32]). Thus, many studies stress that these are the ages in which extra care should be made to encourage girls to follow computer science. Similarly, young girls within this age group tend to learn more and perform better while working in groups; such group work is not a common trait of computer science education within this age group.

> " 'Most children at the primary level have an interest in computers, if given the opportunity, but in the middle school peer pressure tends to direct more girls away from computers.' In addition, at this age girls' preferences for working in groups and their need for demonstrated relevance are especially great" [32, p. 44].

Even if girls initially had an interest in computers, when they reach the ages between twelve and fifteen, many shy away from computer science due to a number of outside influences. One study stressed how girls who are fifteen years old are already making important decisions about their future, since they are choosing which advanced college preparatory classes they will take (see [20]). The study recommended specific programs aimed at girls of this age that were designed to encourage young women to aspire towards a computer science career. The important idea was to stress that such a career can be a very rewarding pursuit. Hopefully girls will be interested in taking computer science courses while still in high school, and ultimately follow a path leading to a career within the field. An idea for one program was planned:

> "Specifically for girls in Year 10, the year in which they are making their decisions on what subjects they will study for their final two years of

> schooling. The challenge was to organize a program that, hopefully, would show the participants that computers could be interesting and fun. The major objective was to show girls who had the ability to work with computers, but who had not displayed any interest in computing, that using and working with computers could be fun and interesting" [20, p. 210].

Many studies stress the need for special programs aimed at girls which would encourage them to think positively about computer science. Another specific program aimed at young women who are midway through high school was a video covering many different aspects of the field. "One way of showing girls some of the more attractive aspects of working in computing is to use a video. There was a need for a video that provided information about computing careers specifically to encourage girls to consider computing" [20, p. 209]. Young women may benefit from such programs that help to demonstrate how careers in computer science can be very positive and attainable goals. Encouraging girls to pursue computers from a young age can be very beneficial to the field. If fewer women are discouraged from computer science in this crucial age period, then the number of women ultimately choosing to study within the field will grow to a much larger and diverse group.

3.1.4 Formalized Computer Science Curriculums

In order to encourage girls to develop an interest in computing at a young age, a number of studies stress the importance of formalizing a computer science curriculum at the secondary level and lower. As the field continues to grow, elementary schools through high schools have had to quickly adapt in order to provide decent levels of education within the field of computer science. Therefore, at times, computer science education at these levels has been somewhat makeshift and chaotic. Studies stress the importance of formalizing a curriculum for the computer science subject at these levels, with the special aim of providing encouragement to girls who may lack any initial interest in computers. One study discusses specifically:

> "the need for a formal computer science curriculum for grades seven through twelve as well as a mandatory requirement that every high school student take an introduction to computer science. In addition, there should be more uniform teacher training that improves computer skills and lesson presentation while specifically addressing the motivation of female students" [32, p. 39].

Formalizing a computer science curriculum for high school students and younger will not only help to standardize education within the subject, but may also help to invite more women into the field. In another example, one study recommended that in order "to encourage high school students to pursue computing in college, the group recommended that college computer science departments 'adopt' highschools" [32, p. 44]. A program such as this "adoption" program would help to introduce high school students to the actual environment of advanced computer science education. With this knowledge, more women may find a fit within the true portrayal of the computer science field, and choose to pursue such a path.

3.2 Altering Computer Science Curriculums

For a number of reasons, many people feel that computer science curriculums should be altered in order to attract a more diverse audience at the beginner level. Computer science classes are currently strongly reliant on mathematical ability, and structural programming is taught at the start. However, many agree that this curriculum attracts boys, and steers girls away. Current forms of computer science education should be altered so that women are not being discouraged from the start.

3.2.1 Single-gender Classrooms

One recommendation that has been made by a number of studies is the introduction of single-gender education at both the class and the school level. This would incorporate either entire schools for all girls that would focus on math and science, or on math and science classes within public schools only for girls. For example, one study "proposed all-female schools focused on math and science" [48, p. 1]. The hope is that this type of education would introduce a wide number of advantages to girls that would help to increase the number of women who ultimately find interest in the field of computer science, as well as other math and science fields.

A number of studies that discuss all-girl classes and schools touch on the fact that this form of education will meet the differing needs of both boys and girls. One study stated that "single gender academies...shall be tailored to the differing needs and learning styles of boys and girls as a group" [48, p. 1]. The idea is that the existing education at secondary levels and under specifically within the subject of computer science may be better suited for boys, and this may explain some of the disinterest that girls tend to show with these subjects.

Some of these studies also covered other benefits that such single-gender classrooms and schools can offer, including:

- "Student academic outcomes are enhanced.
- Desired personal characteristics such as self-efficacy, are demonstrated.
- Academic settings with small classes isolated from negative community surroundings are facilitative.
- Faculty expressly selected to serve the needs of reluctant learners foster increased student attendance.
- Participating students express satisfaction with academies and their environment" [48, p. 1].

Notice that all of the benefits listed above address many of the issues that are suggested by previous studies as possible solutions in reducing the disparity in numbers of women within the field of computer science. For example, girls may develop "self-efficacy" through single-gender education, which may give them more self-confidence in front of the computer as discusses in section 3.2.2. In addition, it is noted above that girls will be "isolated from negative community surroundings." Such surroundings can discourage young girls from finding interest in computers, as was discussed in section 3.1.2. Single-gender classrooms also provide women role models at a very young age. Programs for all-girl classes tend to "focus on same-gender role models and bonding," and "improvement of self esteem and overcoming negative images and stereotypes" [48, p. 2]. If girls are exposed to positive women role models at a young age, they will see that a career in computer science can be attainable as well as enjoyable, as discussed in section 2.6. In addition to the exposure to adult role models, girls in single-gender computer science classrooms are also working with other girls of the same age on the computers. This can help them to have confidence in themselves, as well as show them that they are not the only girls who may be interested in computers, which tends to be the norm in classrooms with both boys and girls. Girls in single-gender classrooms can accomplish tasks as a group. All-girl computer science classrooms would prevent girls from feeling isolated if they were one of very few girls using computers in a standard, mixed classroom.

Creating all-girl classes and schools also further addresses the idea that girls between the ages of twelve and fifteen are particularly susceptible to becoming disinterested in computers, as was discussed in section 3.1.3. "There is improvement... in achievement in math and science among females," and "single gender educational settings are believed to reduce the distraction boys and girls create for each other, particularly during the middle-grade years" [48, p. 2]. Single-gender classrooms may increase the levels of achievement for girls in the subject of computer science where they traditionally tend to lag behind their male counterparts. Girls may develop more self-confidence in the subject of computer science at an age when they are usually inclined to find no interest. In addition, removing the social distraction of having boys in the classroom can relieve some of the pressures that deter girls from the field during these ages.

Single-Gender Classrooms Versus Schools

Notably, there is a strong difference between single-gender classrooms and entire schools that are devoted to the education of one gender. Isolating girls from boys will not educate them on how to react in a male environment. If girls are educated in all-girl schools, they may never learn to deal with an academic environment which boys are a part of. The computer science field is a male-dominated environment; even if girls are very successful in the computer science subject in an all-girl school, they may suffer when they are first introduced into the computer science environment. As discussed in section 2.7.2, girls tend to suffer from diminished self-esteem regardless of their levels of competence in the field. Such reactions may be greater if women are not used to interacting with men in a male-dominated environment. All-girl classes focusing on math and science subjects would benefit girls more because they would still be interacting with boys throughout the day. This environment may better prepare young women for the computer science environment.

3.2.2 Software Packages at the Introductory Level

A number of studies propose that teaching computer applications in introductory computer science courses would help to encourage more women to enter the field. "In order to attract women, introductory computer science classes ought to concentrate on applications rather than on math or programming" [22, p. 2]. Such an approach may encourage many women to enter the computer science field.

> "While men may be passionate about computers, women use computers to solve problems she writes... When women fail to see indications that computers are efficient tools, they may lose interest. However, when men and women use computers as tools to solve problems, both groups perform equally well and like using computers equally" [7, p. 87].

Teaching introductory computer science classes that heavily rely on structural programming turn many people away. These classes tend to rely strongly on mathematical background, and a strong initial background in computing. However, most women who are interested in taking an introductory computer science class do not have the initial interest or background in computer use. Introductory computing courses that focus on software packages would offer that introduction to computers, and give women the confidence with the machine that they need in order to continue on successfully.

> "Researchers have shown that previous experience, feelings of self-efficacy, and mathematical ability, are major predictors of success in computer science courses. Defining self-efficacy as 'the feeling that one is in control of the machine and can make a difference in the operation of the machine,' Bernstein said that this factor, which differs between men and women, may cause women's lower level of achievement in computing. Previous experience often leads to feelings of self-efficacy, she said, and much of that experience results from self-initiated investigations outside of classes. 'How can we offer women the same experience?'... Because software packages 'do real work real soon,' she said, 'women, who perceive computers as tools rather than toys, would see the purpose of computers.' Initial success and accomplishing work bring immediate gratification; exploring is easier and more natural, and mistakes are less costly and visible with databases. Group work, which women prefer, occurs more spontaneously with packages" [32, p. 41].

Thus, "using software packages instead of procedural programming as an introduction to computer science" [32, p. 40] will initially make women more comfortable within the computing environment. Since most women find that they are turned away from computer science because they do not feel prepared nor comfortable with the machine, altering the curriculum in this manner will help to rectify this situation. Women will begin with a comfortable knowledge of the use and workings of computers, and will be able to understand the ideas behind how the code they write actually runs. In this way, women will be in a comfortable position to begin writing procedural programs, and will not have any deficiencies that will prevent them from understanding the workings of code.

Some people feel that an additional advantage of introducing computer science through software packages is that it will initially attract a larger number of people to the field.

> "Each time functional software has gotten further away from the details of the hardware, there has been a cry that computer science is being watered down. But each step has encouraged more diverse people to deal with computers. Serious conceptual understanding of application packages will continue this trend" [32, p. 43].

In this manner, a more diverse group of individuals will begin to study computer science. If a larger number of people start taking more introductory computer science courses, then a larger, more diverse group will continue on. If functional software packages can attract women to studying computer science, then more women will continue on further into the field of computer science.

3.2.3 Interactive Programming

Interactive programming is a new technique that has been proposed as an alternate way to teach introductory programming. It is based on the idea of giving a more realistic, involved introduction to computer science. Currently, "in almost every introductory programming course, we teach computation as sequential problem-solving. A programmer's problem is to describe the series of steps to be taken in order to arrive at some desired result" [61, p. 1]. The way in which introductory computer science is currently taught illustrates the concept of a program as an isolated, serialized chunk of code; however, this idea is unlike software that is currently written or used in industry.

> "Although it corresponds neither to our computing environments nor our work, we teach our students a single-thread-of-control problem-solving view of the role of the computer program: computation as calculation. In this model, the job of a computer program is to start with a problem, calculate its answer, return the answer, and stop. We can dramatically improve this situation — and, as a corollary, all of undergraduate com-

> puter science — with a model of computer programs as simultaneous on-going entities embedded in and interacting with a dynamic environment: computation as interaction; computation as it occurs in spreadsheets and video games, web applications and robots" [63, p. 1].

The benefits of this type of an introduction to computer science are manyfold. First of all, such an approach portrays a more realistic view of the actual work that goes on within the field of computer science. It is more useful to have practical knowledge of programming rather than theoretical, especially if both modes ultimately teach the same concepts. In addition, interactive programming teaches students that the code they write is not an isolated program that runs to completion and spits out an answer. Programming interactively, as is done in software that is currently written, produces code that interactively runs as a part of an entire system. "If we teach this model in the first course, we begin our students with the mindset that their work is part of a dynamically interacting system; their goal is to build a piece (or pieces) which coexist and cooperate and collaborate" [63, p. 2]. Another benefit of teaching interactive programming as an introduction to computer science is how it relates computer science to other fields. Computer science is not a completely isolated and all-encompassing field; it must relate and interact with other disciplines. An interactive approach to introductory computer science helps to illustrate the relation between this field and others.

> "This approach to computation also has the potential to build bridges with neighboring and less-obviously related disciplines. For example, the emphasis on harnessing and controlling the interactions shares much with mainstream engineering. The community model of computation is similar to foundational concepts in organizational science and other social sciences. Indeed, the idea that computation's effect is defined in terms of its (environmental) interactions is almost deconstructionist! All of these fields currently understand the computational metaphor as rigidly lock-step sequential problem solving. Reconceptualized, the truth of computational

practice is much closer to complex systems engineering" [61, p. 4].

Such an interactive approach to introductory programming may encourage women to enter the field of computer science. As was discussed in section 3.2.2, women tend to see computers as tools, and find practical results more useful than theoretical results. An interactive approach to introductory computer science offers a practical manner of coding such as this. In addition, women tend to achieve more promising results when they are not asked to perform tasks from scratch at the introductory level, as was discussed in section 3.2.2. Women may find computer science more interesting and appealing if they see practical results and real-world relevance even at the introductory level. In addition, since an interactive approach to introductory programming relates computer science to many other disciplines, a more diverse group of individuals may be attracted to such a course, and continue to find interest within the field of computer science after completing the course.

3.2.4 Reading Code

In addition to introducing software packages before structural programming as discussed in section 3.2.2, another idea has been proposed that would make introductory computer science courses more appealing to a larger group of people. It has been suggested that students should be taught how to "read" as well as "write" programming languages from the start.

> "Looking at how students are taught to write code, this group suggested encouraging students to read programs. To learn most subjects, especially foreign languages, students do not just write, they also learn how to read...'Computing seems to be the only subject where we teach people how to write without giving them any kind of mental model. A better way is to include reading programs' " [32, p. 44].

Most introductory computer science courses are structured so that students are given a statement of a problem, and a blank solution set. This type of assignment may be appealing to individuals who are "risk takers," or view computers as toys, both characteristics of boys. However, a more constructive way of teaching code would be to introduce programs to be "read." Programming structure may be better understood if one is given a chunk of written code, and asked to find a bug, or given a chunk of written code, and asked to incorporate an additional function. Code "reading" curriculums such as these would attract more women to the introductory computing courses, and offer women more opportunities to increase their self-confidence in front of the computer.

3.3 Increasing the Number of Mentors and Role Models

As was discussed in section 2.6, mentors and role models are extremely important in order for women computer scientists to become successful. Women need mentors in order to gain invaluable information about necessary topics such as funding, research projects, and available positions within the area. Furthermore, women computer scientists need female role models in order to gain self-confidence, and to be reminded that their efforts are not futile, and success is within reach. However, it was also discussed that there is a major shortage of women within the computer science field who can serve as mentors or role models. Recommendations have been made for ways to increase both the number of women mentors as well as the number of women role models within the computer science community.

> "Of course, the only real solution to the lack of role models is to increase the number of women in computer science: recall that only 6.5% of computer science and computer engineering faculty at the Taulbee institutions are female. However, until this situation improves, programs that make successful women more visible can help. Examples are programs that bring women scientists to campuses for a short period of time to give a talk, or for a longer period of time in a visiting faculty position" [50,

p. 51].

It is not possible, as mentioned above, for all women to have female mentors. However, that does not mean that successful women should be invisible to other women who are currently pursuing a further advanced career within the computer science field. Programs such as these, where women from outside institutions are invited to give talks or stay on as faculty, offer additional views of successful women from a variety of places within the computer science field.

3.3.1 Pairing Programs

In order to increase the number of role models for young women in computer science, special programs should be instituted that pair younger women with women who have succeeded in the area where they are now studying. Such programs would increase women students' exposure to positive role models who are women computer scientists. In addition, this allows women at the higher levels to recognize themselves as accomplished computer scientists; as the level of self-confidence for these advanced women computer scientists increases, they will also become better role models for the younger, undergraduate women in the field of computer science.

> "At the undergraduate level, it is useful to design programs in which undergraduates are paired with female graduate students and/or faculty. Examples of successful programs of this kind include one run by the Women's Science and Engineering Network at Stanford University and the Women in Science Program at the University of Michigan. Such programs can have the additional benefit of providing graduate women with the experience of being viewed as capable and successful scientists" [50, p. 52].

Programs such as these tend to provide women at both the mentor and protégé level with positive, successful experiences. Another successful mentor pairing program discusses its strengths and goals as follows:

> "The goal of the Distributed Mentor Project is to match female undergraduates with female professors for a summer of research and mentoring at the mentor's home institution. The program seeks to provide female undergraduates with a model not only for research, but also with a model of a successful female academic" [3].

Through programs such as these, the hope is to provide women undergraduate computer science students with two separate benefits. First of all, to find success within themselves by offering them a chance to work in a research environment and participate as a computer scientist. Second, to be introduced to a woman computer scientist mentor who can serve as a role model for success within the field at more advanced levels.

Role models are very important for young undergraduate women who have just entered into the computer science field. As was discussed in section 2.7.2, women are particularly susceptible to diminished self-esteem during their college years. Giving undergraduate women positive role models can help to show them that they can accomplish their goals. However, it is also important to provide special programs that introduce role models to younger women, at the secondary level.

> "To encourage high school students to pursue computing in college, the group recommended that college computer science departments 'adopt' high schools. Also suggested was cascading pairing: graduate students would pair up with college students, college students with high school students, and so on. This cascading effect at lower levels would decrease dependence on those female computer science professors who are role models... Industry should also provide role models: there should be a large-scale program for guest lecturers from industry to speak to high school students "[32, p. 44].

The idea of "cascading pairing" is to distribute mentors down through many ranks of the computer science field, eventually reaching the high school level. This would give women the benefits of participating in both roles, the mentor and the protégé, at each level. Each of these roles can provide positive aspects for women computer scientists at all levels. In addition, it was recommended that women computer scientists from within industry speak to students at the secondary level. This would expose high school girls to positive role models in the industrial realm of computer science as well as the academic realm.

3.3.2 Men as Mentors

It is apparent that many young women computer scientists will have men as their mentors. It is important to ensure that these women will receive the same level of positive mentoring that they would receive from women mentors. All women computer science students will not be able to acquire mentors in the field who are women, since the number of women at advanced levels is so low. Thus, the majority of women students will be mentored by male computer scientists. However, these men should be educated on the fact that issues may be different for women students, and in how they must address these issues. A well-informed man can serve just as well as a woman in terms of providing a positive mentor for a young woman computer scientist.

> "There is no reason that men cannot serve as mentors for women, given an appropriate sensitivity to the problems that women in computer science may face. Indeed, because the number of women computer scientists shrinks as one progresses through the pipeline, it is unreasonable to expect senior women to mentor all of the junior women. Men in computer science must also support younger women" [50, p. 51].

There is no reason that women should make all-around better mentors, and this fact should be emphasized so that women with mentors who are men do not suffer. In fact, it can also be noted that having a male mentor may have a positive impact on a woman computer scientist that a woman mentor may not be able to provide. That is, a young woman computer scientist with a positive male mentor may develop a greater degree of trust and respect for the opposite sex within the field, which she may not have developed through a woman mentor (see [1, p. 4]).

3.4 Institutional Policies

Outright discrimination and sexual harassment against women in the computer science community should not be tolerated. In order to prevent these situations, formal policies and grievance procedures can be put into effect in areas of academia as well as in industry. Following is a recommendation made by one study to incorporate such policies in order to minimize the number of acts of discrimination against women:

> "It is therefore necessary that departments and universities develop and institute grievance procedures that guarantee confidentiality and freedom from retaliation. We recommend further study of already implemented grievance procedures to determine policies necessary to ensure their effectiveness" [50, p. 53].

Formal policies against sexual harassment and discrimination in both academia and industry, as well as grievance procedures will accomplish two goals. First of all, formal policies should prevent any of these actions from occurring within the computer science environment. Instituting formal policies against overt discrimination and sexual harassment should make it clear that these types of actions will not be tolerated within the computer science community. In addition, formal grievance procedures should make it easier for women to come forward with complaints about coworkers. A woman should not be made to feel any more uncomfortable than she already is if she suffers from sexual harassment or discrimination. Grievance procedures should make it as easy as possible for women computer scientists to report any actions that they have experienced. Policies such as these help to emphasize that:

> "Sexual harassment will not be tolerated. Individuals in supervisory positions, such as professors or managers, should make it clear that they will not tolerate sexual harassment. Not only would this discourage such

> behavior, but harassed females presumably would feel more comfortable reporting any problems that do occur to supervisors who have made it clear that they are aware of the possibility of sexual harassment and want to fight it. One way an EECS department head did this was by announcing during a graduate orientation session that sexual harassment was unacceptable and that any harassment victims or witnesses should alert someone in a position of authority" [65, p. 22].

These types of procedures would make it apparent that discrimination and harassment of women computer scientists within the environment will not be tolerated. In addition, women and any other witnesses should feel comfortable about reporting such incidents, so that these incidents may be prevented further in the future. A group of women graduate students gave the following recommendations to academic institutions:

> "Demonstrate a formal commitment to providing a positive educational environment for women. In particular, the administration should
>
> - Publish a formal policy statement articulating this commitment.
> - Establish a formal grievance procedure that addresses both overt discrimination and the subtle inequities that contribute to a woman's discomfort with the environment" [65, p. 25].

In terms of industry, one recommendation is that:

> "companies should print guidelines prohibiting sexual harassment and distribute them to all employees. Those guidelines should be followed up with training... Managers should treat any complaints of sexual harassment seriously. The company should have a clearly enunciated policy of progressive discipline, ranging from warnings to terminations, depending on the severity of the offense" [67, p. 6].

A woman computer scientist within the industry should be encouraged to speak up if she experiences any form of sexual harassment. It is important for everyone in the computer science industry to know that "a company is forbidden by law to retaliate against anyone making a sexual harassment complaint" [67, p. 6]. Women must be made to feel as comfortable as possible in making any form of complaint about sexual harassment in the computing environment.

3.5 Preventing Offensive Pornography

As discussed in section 2.3.3, the display of pornographic material within the computer science environment can have a very detrimental effect on women within the field. This type of demeaning behavior is unlike anything that men in computer science must face. Academic and industrial institutions can encourage individuals to avoid posting any kind of material that might offend other members of the community, such as the use of pornographic images as computer wallpaper. At Carnegie Mellon University, a number of graduate students as well as members of staff made a formal appeal to the CMU community regarding the use of pornographic material as computer wallpaper. Following is a section of that appeal:

> "When a woman sees such a display on your workstation... she may feel that you could be a source of sexual harassment, and feel hostile towards you, or nervous about working with you... Among the visitors to the department... there are surely some who will view us as unprofessional if they see these displays, and this hurts us all, too. Conversely, an environment more hospitable to women – specifically, one in which relations between women and men are less strained – is of clear benefit to men as well. For some people, displays of naked women on workstations, or elsewhere in offices, remind them of the forces in our culture that view women as sexual playthings, not as men's peers... People who are offended will interpret such displays as derogatory, even if that is not your intent. We therefore ask you to refrain from using them out of respect for those

who are offended, even if you believe the offended people are just overly sensitive" [64, p. 2].

However, such encouragement may also be viewed as a form of censorship. It can be argued that an individual should be able to view or post any image that he or she desires. The CMU appeal in turn elicited some negative responses from a number of members of the community, noting that it was a form of censorship. On the other hand, it should also be noted that "the courts have held that sexually explicit posters hung on walls can create a hostile work environment. Similarly, pornographic computer programs or screen displays, particularly if visible to passers-by, could constitute sexual harassment" [67, p. 6]. Although some individuals may find that statements such as those made in the CMU appeal may constitute censorship, such statements when used as encouragement towards other members of the community may have a positive affect for many women. Individuals who display pornographic material may not know that it affects women in such a way, and demeans women computer scientists as professionals. Reading statements and appeals such as these may enlighten them, and encourage them to be more sensitive to others. It is important for individuals to know to what extent they may be offending other members of the community. The computer science environment should be a professional environment, and offenses such as these towards other members of the community should not be taken lightly.

3.6 Re-Opening the Pipeline

As discussed in sections 2.3 and 2.5, women tend to drop out of the computer science field at a much higher rate than men. For women, a major reason for this is family responsibility, and the rearing of their children as discussed in section 2.5. Once women computer scientists have dropped out of the field, re-entering to finish a degree or begin the goal of a new career seems to be a very daunting prospect. Many women find it too frustrating or challenging to re-enter the field, and so choose not to. Because of this, the computer science community is missing out on a large number of women who would choose to be successful computer scientists if re-entering the field were an easier process. In order to increase the number of women in the field of computer science, it should be made easier for women to re-enter the field once they have dropped out.

3.6.1 Altering Tenure Structure

As mentioned in section 2.5, balancing the demands of a family and attempting to earn tenure is nearly impossible for a woman in the computer science field. For this reason, many women feel that if a choice must be made, they will have to drop out of the computer science field. However, one way to prevent this is to alter the structure of tenure so that bearing children does not interfere with earning tenure. A number of studies have recommended "changing the tenure structure to allow a more flexible timeclock" [32, p. 43]. In this manner, women will no longer feel the need to make a rash decision about sacrificing their tenure.

> "Some kind of reduced work load is essential to permit faculty members who wish to do so to better balance their family responsibilities with their careers... The worry is that if this happens, the default tenure period will simply become seven years instead of six, and women who do take primary responsibility for the rearing of their children will once again be at a disadvantage... It appears that one solution is to make a strong effort not to change the standards for tenure. That is, departments must continue to impose the same tenure requirements as they do now, but must assume that some faculty members will take seven or eight years to meet those requirements instead of six" [50, p. 54].

If the tenure structure were maintained in this manner, there would be more flexibility for women computer scientists, and it would be more feasible for women to earn tenure as well as bear children. Thus, women academics would ultimately be far less inclined to drop out of the field of computer science.

It should be noted, however, that a number of universities have informal, undocumented policies on altering the tenure structure. For example, if a woman must take time off for pregnancy leave, some institutions may choose to grant her an extra year to complete her tenure. Formalizing such programs may help to encourage more women to enter the field; women may realize that dealing with both professional and family responsibilities may not be such a daunting prospect after all.

3.6.2 Re-Entering Academia

Many women tend to drop out of the field of computer science before they have completed their degrees, or choose to work elsewhere in industry, outside of the computer science field. As a solution, policies and programs should be instituted that make it easy for women to re-enter the field. For example, women should be able to re-enter academia if they want to earn an advanced degree in the field of computer science. In addition, women should be able to work as a computer scientist in industry if they had previously earned a degree in computer science but chose to work outside of the field for some time.

> "An additional approach to correcting the problem of under-representation is to help women re-enter the pipeline after dropping out of it early. One particularly successful re-entry program... is aimed at making graduate study in computer science possible for women who have received a bachelor's degree in another field... A second set of women for whom reopening the pipeline may be useful are those with science degrees who are not employed in science" [50, p. 55].

If a woman earned a degree in computer science but initially chose to work outside of the field of computer science, it should not be a difficult task for her to choose to re-enter the field. Encouraging women to re-enter the field after leaving it may greatly increase the number of women in computer science.

Along the same lines, policies which may discourage women from entering the field of computer science academically from another field must be revoked. For instance:

> "At Berkeley, there were restrictions on transferring between, for example, Liberal Arts and Engineering; net result was to prevent many women

> (who are socialized differently than men are and may identify their interests later than men do) could not make the switch when they belatedly discovered their interest in Engineering" [1, p. 8].

Restrictions such as these which prevent individuals from moving from one discipline to another will have negative effects for women who ultimately decide that they have an interest in pursuing computer science. Abolishing such restrictions may increase the number of women within the computer science field.

However, it must also be noted that such restrictions serve a purpose for both the academic institution as well as for the students. That is, universities may require students to declare a major and remain within it so that the amount of resources for each major may be regulated. If individual students are constantly switching majors, certain departments may be overwhelmed by students, and may lack the resources to accommodate them. In order to benefit women computer scientists, it may be necessary to alter the restrictions slightly in order to accommodate those who are making a well-informed decision about a new career path, while still preventing other students from aimlessly changing majors and depleting departmental resources.

3.7 Women Founding Technical Companies

Many women have left the standard field of industry in order to found their own companies as a result of the discouragement and the frustration that they face when they realize that their chances of promotion are lower than that of their male counterparts. "More women than ever before are encouraged to start their own technology firms instead of just rising through the corporate ranks" [12]. As was covered in section 2.7.4, women in the computer science field are promoted less frequently than men within the upper ranks of both industry and academia. Eventually many women realize that they will not be promoted to a level they are capable of attaining or that a man with the same qualifications would be promoted to. As a result, many women have chosen to leave the traditional path in industry in order to start their own technology companies. For example, one woman took the cue and decided to start her own company; furthermore "the fact that she didn't see a lot of women in senior positions at technology firms was part of the motivation for her move" [12].

Overcoming the fact that women computer scientists are promoted less frequently than men is not the only issue that startup companies can help to solve. A number of other problems that women computer scientists face can be addressed by encouraging more women to found their own companies based within the computer science field. In fact, "51% of women business owners with prior private-sector experience cite the desire for more flexibility as the major reason for leaving corporate positions, while 29% cite glass ceiling issues" [15]. The majority of women who decided to found their own companies stated that flexibility was an even more important benefit than overcoming the glass ceiling issue. As was discussed in section 2.5, many women computer scientists are forced to juggle the responsibilities of a family and a job within the field. Women find that traditional technology companies as well as academic institutions are too rigid when it comes to family responsibility and child care. Women who start their own technology firms can increase the support for individuals with family responsibility, and provide stronger childcare programs.

However, it is not always possible for women computer scientists to start their own companies; doing so requires large efforts, both financially as well as with regards to time. Acquiring financial support is difficult for women who are starting their own technology companies. In fact, "studies show that only about 2 percent of all venture funding for technology firms goes to companies run by women" [11]. In order for founding new companies to provide a means for women to find more success within the computer science field, such financial drawbacks must be overcome.

It must be noted that women computer scientists who successfully found their own companies may also run into the same discrimination they would have had they remained in industry. For example, if managers and other employees overlook a woman's professional software development skills while she works in industry, she may run into the same problem with her own company. Here, her entire group of products may be overlooked because they were produced by a company run by a woman. Therefore, much care must be used in founding a startup technology company. Leaving standard roles in industry is only a first step; others must be enlightened about the continued discrimination against women as professional computer scientists.

Chapter 4

Solutions Through Technology

There are a number of ways in which existing computer technology can be used as a way to increase the number of women within the field of computer science. Some of these technologies include remote access, on-line communities, email, and Internet repositories or sites with large, organized amounts of information. For instance, remote computer access would allow individuals access to computing resources from their home. In addition, there are a large number of groups of women within the field of computer science who have joined together, both on-line and off-line, to discuss issues that women computer scientists face. Most of these groups are initially formed through some type of networking. Many on-line groups of women begin with two or three women emailing one another, and eventually the group may expand into hundreds or even thousands of women.

There are also a number of groups of women who join together off-line to discuss women in computer science. Off-line communities are generally formed in the same manner of networking. A few women may gather together to discuss their issues, and these meetings may grow into large meetings. Another way that off-line groups are formed is through spin-offs of other groups. Women may gather once a year at a conference on women in engineering, and then decide that they want to meet again before the next conference, and form their own community to discuss the issues that affect their lives as women computer scientists. Furthermore, Internet repositories are sites on the Internet where large amounts of information can be stored. Information on women in computer science and programs used to increase the number of women in the field can be gathered and efficiently stored on one site. Technologies such as these can be used to help increase the number of women within the computer science field.

4.1 Virtual Identities and Virtual Gender-Swapping

CMC [Computer-Mediated Communication] refers to MUDs [Multi-User Domains], IRC [Internet-Relay Chat], email, and any other form of computer technology that is commonly used as a means by which computer users can communicate with each other. What is interesting about such forms of communication is the freedom which it can provide users in terms of defining oneself to other users. Through the use of CMC, an individual's identity is more flexible in terms of how it can be portrayed to his or her peers. When communicating using a computer, many of the general forms of personal interaction that individuals must deal with through traditional forms of communication do not exist. For example, there is no face-to-face interaction, so there are no visual cues for other users to go by in constructing another's identity. Although this is also true for communication by telephone, there is the additional fact that audio clues are absent in communication through the use of a computer. In this way, users are quite free to develop and portray an identity that is as real or as make-believe as they desire. What an individual types at the keyboard is the only thing that others can go by in forming that person's identity.

It is apparent that CMC allows much freedom to individuals in terms of how they may choose to define themselves on-line. For instance, users have the choice of portraying a true identity of themselves by remaining true to their real-life characteristics. In a slightly different manner, users may decide to stay as real as possible by changing only small characteristics about themselves. That is, one could claim to wear glasses in a description of oneself on-line, whereas in real life he or she does not. Most interestingly, users can portray any type of personal identity that they want, as long as they are convincing enough to those that they are communicating with.

The choice of an individual's identity is especially relevant to this thesis in terms of gender. Users can choose to be their own gender, or choose to play a role as the opposite gender while on-line. Virtual gender-swapping is the act of portraying oneself as a member of the opposite gender while communicating by use of a computer. This idea of gender-swapping on-line may have both positive and negative consequences concerning women in the field of computer science.

The opportunities that virtual gender-swapping provides to users are frequently debated. Some argue that CMC allows for the destruction of standard barriers that exist in our society, while others argue that it actually enforces such barriers. On the other hand, some argue that such virtual gender-swapping allows individuals to hide behind a falsely constructed identity in order to avoid the standard rules of society. What is important to discuss about both sides of the virtual gender-swapping debate is the opportunity that computer technology provides in defining gender roles. On one hand, virtual gender-swapping may allow opportunities for new, different social constructions; alternatively, computer technology also allows society another means by which to enforce barriers defined by gender that already exist.

4.1.1 Destructing Barriers

Computer-mediated communication can allow for users to overcome standard barriers in society such as race, class, and gender. When communicating over the Internet, other users do not know what one looks like, or what job he or she has.

> "What is novel are the opportunities CMC presents not only to limit the visibility of one's identity, but to present alternative, and perhaps entirely fictional identities. When all anyone knows about you is what you choose to call yourself, and what you type, you can pretend to be anyone or anything" [13, p. 5].

Others can only conclude things about a person's identity using what a user states about oneself through the keyboard. This may allow computer users the ability to overcome obstacles that they typically must face in our society. "One of the greatest strengths of email is its ability to break down socio-economic, racial and other traditional barriers to the sharing and production of knowledge" [13, p. 4]. Specifically, these ideas are important in terms of women in computer science. The ability to deconstruct barriers of gender that traditionally exist in our society can have positive effects on women. CMC can offer women the ability to challenge traditional roles that they have been carved into, and openly defy such roles. "IRC enables people to deconstruct aspects of their own identity, and of their cultural classification, and to challenge and obscure the boundaries between some of our most deeply felt cultural significances" [52]. Thus CMC can offer users the ability to transcend barriers that they have traditionally been held back by.

4.1.2 Opportunities to Hide

On the other hand, many argue that virtual gender-swapping is not advantageous to the plight of women in computer science, and may in fact be harmful. While CMC may offer a woman the ability to transcend any barriers she faces because of her gender, it may actually be encouraging her to hide behind the standard role of a man. That is, instead of declaring that she is a woman and still able to behave as an equal regardless of her gender, virtual gender-swapping allows women to deny the fact that they are female. Thus, it may be enforcing society's gender boundaries by allowing women to acknowledge the existence of those barriers and choose to masquerade as men in order to avoid any discrimination or inequality that such barriers create. Women may portray themselves as men because of "a desire for invisibility or permission to be more outspoken or aggressive" [68, p. 221]. In order to avoid any restrictions that women may feel are placed on their behavior in traditional society, they may choose to hide behind the male gender.

Choosing to hide behind a falsely constructed identity based on gender may be simply an acknowledgment of the fact that barriers do exist in society for women. Rather than helping to break down barriers, virtual gender-swapping by women may be enforcing such boundaries. When women choose to define themselves as men on-line, they are declining an opportunity to help transcend barriers that exist against women in society.

Male Virtual Gender-Swapping

On the other hand, men may also be using virtual gender-swapping as a way to hide from traditional gender stereotypes that society holds. For example, one man states that he masqueraded as a woman on-line in order to hide behind more feminine behaviors:

> "I wanted to know more about women's experiences, and not just from reading about them...I wanted to see what the difference felt like. I wanted to experiment with the other side...I wanted to be collaborative and helpful, and I thought it would be easier as a female...As a man I was brought up to be territorial and competitive" [68, p. 216].

Virtual gender-swapping is indeed a way for individuals to hide from the standard stereotypes that define what is expected of them based on their genders. This technique may therefore simply be a means of acknowledging the fact that barriers do exist for women in computer science. In addition, it may encourage women to avoid dealing with a serious problem that they must face on a daily basis within the real world.

4.1.3 Technological Construction of Gender

It is apparent that virtual gender-swapping does offer society the ability to reconstruct ideas about gender. "Regardless of individual motivations, one thing is certain. The choice of gender that MUDs provide is a tool which forces users to examine their preconceptions about gender and gender roles, sexuality, role playing, and identity" [44]. However, it is unknown which direction this construction will follow. It may follow the standard path of gender definitions that already exists, in which women are not always seen as equals to their male counterparts. On the other hand, it is possible that there will be a new construction of our ideas of gender that challenges traditional roles for men and women. A positive construction such as this could be beneficial not only to women within the computer science field, but to all women in general.

> "It is argued that the net is a utopia of sexual freedom, and that we lose our identity as we dip into a haven of equality, removed from the discrimination of the 'real world' — on the other hand, there are those that think the corporate net is nothing more than a capitalist, sexist con, permeating outdated notions, whilst pretending to dispel them.
>
> Some of the questions behind the Cyberfeminism debate are:
>
> - Has the information superhighway brought with it a totally genderless arena for free speech and asexual contact?
> - Have we done away with out-dated patriarchy by logging on and booting up?" [24]

Most forms of CMC are relatively new and have not reached a state of general use in our society; face-to-face and telephonic communication are still the standard throughout the world. While standard CMC guidelines for interpersonal communication are still being formed, a technological construction of gender is taking place. If new ideas of gender roles were to be developed, such communication would be beneficial to women as well as the whole of society. On the other hand, the role of gender that will be constructed in the technological realm could follow standard roles that currently exist. A traditional gender breakdown can only have negative effects on the computer science community, since it tends to promote the issues that women computer scientists must face.

Negative Technological Construction of Gender

Since CMC has not been around long enough to develop strong interpersonal communication guidelines, there still exists the freedom to define new ways of thinking about our society's standard gender breakdown. If communicating through the use of computer technology follows the same path as society's general boundaries, women will still suffer from inequality within the computer science field. A number of people argue that although CMC has the ability to transcend society's gender barriers, it is actually falling prey to those barriers and enforcing the behavior that they create.

> "Despite cross-gender MUD play sounding as though it could potentially destabilize the binary gender regime, it in fact seems to be a manifestation of that very structure. The malleability of identity online, both in MUDs and in other forms of CMC, is in no way guaranteed to foster more equitable relations, in either virtual or real life. In fact, we oughtn't be surprised if existing structures regulating social life manage to shape online life in their own image, fixing what is now malleable so as best to perpetuate themselves" [13, p. 7].

If nothing is done in an effort to intentionally redefine the traditional gender stereotypes in the technological realm, then the gender dichotomy will most likely remain status quo. It is notable that a sincere effort must be made not to condone a negative stereotype for gender roles. It is possible that a positive change can take place through technology, but if no effort is made things will most likely remain the same.

Positive Technological Construction of Gender

It is possible that through CMC there could arise a new technological construction of gender which would differ from society's traditional gender roles. This could be one of many positive "effects of computer-mediated communication (CMC), a medium that appears to hold promise for a reforming of individual and societal conceptions of gender and identity"[41, p. 1]. Rather than holding true to traditional gender roles, technology could develop a world in which gender does not create any barriers. As men and women have begun to experiment with virtual gender-swapping, society's rigid roles and barriers for women have become clear for many. Individuals can take what they are realizing through such experimentation and use it to break down standard inequalities between the genders. As more individuals find themselves portraying a member of the opposite sex, society's rigid barriers become more visible. Notably, many people find these initial experiences to be uncomfortable.

> "For some, this is where cyberspace ceases to be a comfortable place. We are so used to being provided with information about each other's sex that the lack of it can leave many players feeling set adrift. Gender roles are so ingrained in our culture that for many people they are a necessity, and acting without reference to them seems impossible... Much as some of us may deplore what we see as the negative sides of our culture's sexual politics, we are brought up to align ourselves with gender-specific social navigation mechanisms. Once deprived of the social tools which I, as female, was used to deploying and relying on, I felt rudderless, unable to negotiate the most simple of social interactions... It took much practice to learn to navigate these unfamiliar channels, an experience that gave me a greater understanding of the mechanics of sexual politics than any other I have ever had" [53].

Virtual gender-swapping alerts individuals to how deeply ingrained society's standard gender roles are. However, many individuals find that portraying the opposite gender eventually becomes more comfortable as they become attuned to their reactions to society's gender stereotypes. As people learn that negative gender-based boundaries are so strongly ingrained, it becomes apparent that CMC can provide a means of changing traditional roles. As individuals begin to break down the standard gender dichotomy by freely choosing one's gender, the rigid gender roles may become obsolete on-line.

In addition, CMC and computing technology provides another window into the fallbacks of traditional gender roles. Masculine behavior has traditionally been linked with the rational and logical, while feminine behavior traditionally aligns with the irrational and emotional. For these reasons, women's roles have always tended to lie outside of the realm of technology, and specifically computer science. Women have traditionally been seen as less productive in such fields. However, if society's standard gender roles can be broken down and seen to be false, women may then be treated as equally competent within the computer science field.

> "Traditionally masculinity has been linked with the logical, technical and rational while femininity has been linked with the emotional, intuitive and irrational... Such cultural representations of gender have led to the division of spaces and activities designated as more suited or productive for one gender rather than the other. On the other hand, deconstruction of such representations and discourses have pointed to new ways of thinking about gender spaces and activities resulting in more blurrings of gender boundaries and a re-mapping of gender terrains. The new femininities which seek to challenge the old structure of positing women as illogical and irrational have led to a movement towards the public, 'rational' sphere for women"[53].

A construction of new roles for the genders can arise through the means of computing technology. This new technological construction of gender has the possibility of enforcing less rigidity of roles based on gender. It can help to unveil the fact that traditional gender roles are not strictly formed in reality. Women can find a strong representation in technical fields such as computer science, which are based in the logical and rational. Women will no longer be held back from such fields based on the fact that they are traditionally viewed to be more productive in the irrational and emotional realms of society.

4.1.4 A Small Step in the Right Direction

It must be emphasized that the computing technology that offers opportunities such as virtual gender-swapping alone cannot change society's traditional gender roles and stereotypes. Virtual gender-swapping may provide individuals with a strong grasp on the fallbacks of traditional gender boundaries and alert them to the changes that need to be made. However, actually instituting positive change must be accomplished through other means. Masquerading as the opposite gender may provide an individual with an understanding of society's barriers, but doing so alone will not break down those barriers. People must also make an effort to accomplish goals such as forming groups both on- and off-line in order to discuss the issues that virtual gender-swapping brings into light. Understanding the issues and realizing that something should be done in order to redefine standard gender roles is merely a first step. Individuals must then use this knowledge to institute change within the real world.

4.2 On-line Communities for Women

Computer technology can be used to unite women within the field of computer science in a way that would be physically impossible otherwise. Using technology such as on-line forums, email lists, and on-line chat groups, women within the field can easily communicate with one another across the country and even across the world in ways that they could not in person. Women in computer science can join together with other women in different areas of the field, or with women in similar areas of computer science but who are difficult to get in touch with through any other means. Whereas it may be impossible to meet with women in person from different parts of the world more than once a year or engage in regular phone conversations, on-line communication can take place on a daily basis at very little cost. Communication by telephone overcomes physical boundaries since one can talk to others anywhere at any time, but it also has its limitations, namely that it is costly and depends on timing. On the other hand, on-line communication is relatively cheap, does not depend on local time zones, and does not require users to be present at the receiving end of the transmission as a telephone call requires.

On-line communication has a number of other advantages, besides that of overcoming physical barriers. Users frequently find it easier to communicate on-line using the written word rather than communicating in person or over the telephone. In addition, individuals communicating on-line have more time to respond honestly and helpfully, and can easily keep a record of conversations or important information that was exchanged. Individuals "often feel less intimidated or hesitant asking questions using e-mail than they might posing those same questions in person or over the phone. Email also makes it easy to communicate thoughtfully and deliberately, and provides a record of communication" [46, p. 1]. These aspects are simply not as feasible when communicating off-line.

4.2.1 Open On-line Communities

Open on-line communities, that is, those which are available to both men and women, can be a beneficial way to reduce the disparity in numbers of women within the field of computer science. However, many times a lot of effort in general open forums is spent on arguing about the existence or seriousness of issues that women computer scientists must confront. This type of hostile communication is not beneficial to instituting change within the computer science environment. Open on-line communities can be organized specifically to attract only individuals who are interested in improving the problems that women computer scientists face. In this way, open on-line communities can also be a very successful tool for the field. If such communities can be created between men and women who all have the positive, sympathetic goal of discussing issues and presenting possible solutions, then there is no reason why such forums cannot provide a means to increasing the numbers of women within the computer science field.

> "If men work together with women in an open forum and are seriously interested in hearing what women have to say, rather than in telling us what we need, then such a forum could be a fruitful and productive addition to the computer science community" [10, p. 3].

Open on-line communities must also be an integral part of improving the situation for women computer scientists because women must eventually feel comfortable interacting with men. Open on-line communities provide a positive, mixed environment in which women can feel comfortable discussing their problems with both men and women. In addition, open on-line communities are the area in which individuals can experiment with virtual gender-swapping. If virtual gender-swapping can serve as a means to reconstruct society's traditional gender roles, then open on-line communities can be the tools to achieving this goal.

4.2.2 All-female On-line Communities

Open on-line communities allow users to masquerade as the opposite gender. However, as mentioned in sections 4.1 and 4.2.1, men may take advantage of these opportunities to harass women. Therefore, women also need on-line communities that offer them a haven in which to communicate with the guarantee that the other members are all women. All-female on-line communities are groups that specifically exclude men by definition. Such all-female groups of women can be very helpful for women in the field of computer science for many reasons. Open groups that are meant for general members of the computer science community, that is, on-line communities that are open to members of both sexes, can be very helpful in their own way as discussed in section 4.2.1. However, open on-line communities have a major flaw: they maintain the same minority population of women that exists in the physical computer science community. They create a larger pool of individuals to discuss issues, but do not ameliorate the problem of the under-representation of women within the actual environment. Such groups do not improve any of the issues facing women computer scientists because women are still widely outnumbered. That is, open on-line groups "can improve communication by introducing us to a larger community, but do nothing to reduce the disparity in numbers" [10, p. 1]. Women need a group of their own so that they may feel comfortable in discussing their issues. All-female on-line communities can provide women computer scientists with a haven in which to talk about the problems that they face without getting into arguments about the existence or seriousness of such problems.

> "Many open forums whose focus is women's issues suffer from a common problem. Discussions are frequently dominated by disagreements between men and women about what the issues are rather than how to deal with them. This is not a problem with all men, but is a problem with almost all

such open forums. Women more often share common ground that allows us to get beyond defining issues and on to constructing solutions" [10, p. 2].

The benefit of all-female on-line forums is that they consist of a group of women who are interested in discussing the issues that women computer scientists face. Such forums do not frequently suffer from members participating in arguments about the basis of complaints and issues concerning women within the computer science field. Instead, the women members populating all-female on-line forums agree on common issues and can openly discuss them together. The hope is that women interacting in this way can help to prevent problems in the future by finding solutions to issues that women computer scientists face, as well as providing a safe haven to discuss issues directly facing them. In an open forum, much time is spent on debating whether some of the issues actually exist. In addition, many individuals in open forums tend to question whether the problems discussed are as difficult as some make them out to be. All-female forums tend to avoid these problems, because the women are there to solve the problems, not to doubt their existence. All-female on-line forums provide women with a place where they may safely discuss issues with others who are sympathetic to their problems, and attempt to propose possible solutions.

Systers

Systers (*www.systers.org*) is a successful all-female on-line forum was created as an arena in which to discuss the issues that women computer scientists face. Systers was founded in order to bring together a minority of the computer science field, in order to safely discuss the issues confronting them, as well as promote solutions in a positive environment. A summary of the Systers forum follows.

> "Systers is a private, unmoderated but strongly guided, mailing list [now also a web-based forum] with a documented set of rules for participation. The membership of the list includes female computer professionals in the commercial, academic and government worlds as well as female graduate

> and undergraduate computer science and computer engineering students. Systers currently has over...2500 [members] in 25 countries...We are a global community of individuals who are otherwise physically isolated from each other. Systers is not analogous to a private all-male club. It is different because women in computer science are a small minority of the community. It is different because systers is not interested in secrecy or in keeping useful information from the rest of the community" [10, p. 1].

Systers is very successful as an all-female on-line forum partly because of its ability to unite such a diverse group of women. Systers successfully brings together women within the computer science field worldwide. Issues facing women computer scientists are not exclusive to one region; they are issues that exist internationally. In addition, Systers has the ability to accomplish goals that help to relieve some of the problems that women computer scientists face. The Systers community not only discusses problems that many women computer scientists must confront, but also strives to invent and institute solutions to the problems. Soon after its creation, Systers was "opened to all women in technical areas of computer science. Gradually, the list became an effective means of communicating and united a previously disjoint group into a geographically diffuse but well-connected community. It also became a powerful mechanism for exerting influence and effecting change" [8, p. 1]. Systers uses computer technology as a way to connect women computer scientists across the globe with the hope to institute change within the field.

The creator of Systers as well as individual members of the on-line forum have met with considerate opposition regarding the institution of an all-female forum that specifically excludes men. In response, they state that "Systers is not intended for men, however sympathetic, as experience has shown this tends to dilute the purpose of a special forum just-for-us, where we don't have to spend energy explaining issues to a different point of view" [8, p. 2]. Systers was created as an all-female on-line forum where women computer scientists can meet to discuss their issues and propose solutions without having to face resistance from individuals who may doubt many aspects of their issues. Systers has proven to be a successful forum in which women within the computer science field can meet to talk about their professional issues, and find ways to make the computer science field more inviting and comfortable for women computer scientists.

4.2.3 On-line Security

All-female on-line communities have the requirement that all users must be female. It is important to the proper functioning of all-female communities and forums that this requirement is met by all members. It should be guaranteed that only valid members of the community are allowed access to both the forums and the actual identities of other members. In addition, there should be a way to guarantee that only women are being granted membership to all-female on-line communities. If a member is actually a man masquerading as a woman, then the safe, honest environment described in section 4.2.2 may be compromised. Furthermore, an individual's gender is not always the only characteristic that should be verified. If a community is meant only for professional computer scientists, then any other individuals should be denied membership. Outsiders attempting to gain access or membership for commercial or other purposes should be carefully screened out. However, it is not an easy task to guarantee that every individual applying to become a member of an on-line community fits these requirements. Security becomes an issue when users' personal identities are being moderated.

Thus, there are two separate security issues that must be addressed concerning on-line communities. First of all, only valid members of the communities must be granted access to the forums, whether the resources available are Internet sites, bulletin boards, or email lists. Additionally, only individuals who meet the requirements of the forums must be granted membership. If both of these requirements are not sufficiently met, then the forums may be compromised.

The first security need, that of guaranteeing that outsiders cannot gain access to resources of an on-line forum, is dependent on two things. First, it depends on the security of the technology being used. An Internet site is only as secure as current technology can provide. An Internet site or bulletin board should require some form of secure user verification. Additionally, guaranteeing that non-members are not acquiring information from the forum depends on individual members as well. That is, even if it is guaranteed that only valid members are directly accessing information concerning the forum, members may be disseminating information to outsiders. Regardless of how secure a resource is in terms of allowing access to information, there is no guarantee of what validated users will do with that data. Therefore, some amount of trust must be placed on individual members of on-line communities.

The second security need of on-line communities is guaranteeing that only individuals who meet the requirements are granted membership. This security requirement is harder to meet, in that it relies more on the trust of individuals, rather than on the security of computer technology itself. It is not guaranteed that every individual can be adequately screened as part of an application process. For instance, the Systers application form requires that an applicant submit the following statements:

- "A description of your involvement in technical computing
- A statement that you are female
- A statement that you are willing to observe the Systers guidelines" [66].

If member screening is limited to such statements, then the validity of all members is not adequately secure, since it relies completely on individual trust. However, increasing the screening process beyond this point eventually reaches a point of unfeasibility. For instance, it is possible to check whether an individual has earned a technical degree or is currently a student in a technical field, but many other characteristics are more difficult to verify. It is not feasible to verify the gender of an applicant for an on-line community. If an individual wants to hide his or her gender, he or she may do so without repercussions. It is considered a violation to try and determine an individual's gender without his or her permission. Therefore, the security of on-line groups must eventually rely on individual trust to some degree.

Another recommendation would be for an additional measure of security to require another form of screening for potential members. Communities could require that individuals requesting membership must be recommended by a valid member of the community. That is, a user who is already a trusted, valid member of the community must be willing to vouch for an individual who is applying for membership. Such a requirement would help to form an integrated, trusted community.

4.3 Problems of On-line Communities

A major problem with utilizing on-line communities as the only means of communicating about the issues that women computer scientists must face deals with society's traditional definition of intelligence. In general, society has always had strict definitions of what it means to be "intelligent" in the technical sense. Intelligence has been gauged on one's ability to solve logical problems, and to reason objectively without the consideration of emotions. In particular, artificial intelligence, a field which in some cases attempts to mimic human intelligence through a complete, is based on this definition. However, many are arguing that this definition of human intelligence should not hold true. One's ability to strictly reason through a mathematical problem should not be the basis of intelligence. The argument is that a well-developed human has many more capabilities that go beyond strictly objective reasoning. Using all of these abilities in conjunction can provide an ideal level of interaction with the world.

> "Classical AI approaches try to build intelligence by implementing isolated parts of intelligence; standard topics are chess playing, theorem proving, and problem solving... The men who started AI were mathematicians, experts in their field, and so these skills came naturally to them. 'And they said, hey, if it proves a theorem or plays chess, it must be smart' (Athanasiou 1985, 17). However, they ignored the fact that other people might select totally different skills for defining intelligence. Especially women, because of their daily experience, might choose different abilities: They often value social skills more highly than abstract, disembodied tasks. Ac-

> cording to the feminist critique, the skills chosen by mathematicians are not only disembodied but estranged from any human's daily experiences" [28, p. 101].

Many people believe that an individual's overall intelligence should be based on one's ability to completely interact with the world. Ideal interaction is not simply based on objective reasoning. One must confront stimuli within the environment, as well as draw from one's emotional reactions to such interaction. Embodied AI tends to differ from classical AI in this manner. Embodied AI strives to incorporate many human interactions and reasoning into the machine view of human intelligence.

> "Embodied AI researchers take this critique seriously and redefine intelligence as the ability not only to interact with a constantly changing environment but also to act socially. The ability to act socially and form relationships is one of the most important tasks for survival. Chess and theorem proving are here seen as by-products and not as the core of intelligence" [28, p. 101].

The argument is that an overall subjective (accounting for emotions) as well as objective (strict reasoning) view of intelligence should be the general definition of human intelligence. Individuals should not be made to feel technically inferior because they are unable to strictly rely on objective thought and ignore emotional reactions. Emphasis should be made on the fact that positive emotional reactions are needed to ideally interact with the world in any setting.

A different view of intelligence can benefit women within the field of computer science. Women will not be made to feel less competent strictly because of the assumption that women are irrational "by nature." This advantage is two-fold. First of all, individuals who reason better using some emotional interaction will also be productive within the field. Additionally, it will not be assumed that women are irrational beings who cannot be productive in a rational world. Women will be comfortable within the computer science field without being judged on false assumptions about technical intelligence and women's inability to acquire it.

On-line communities are somewhat problematic because they depend on this disembodied view of intelligence. That is, when users are communicating only by means of a computer, their means of interaction are abstractions that involve only what they are typing at the keyboard. Therefore, the communication takes place at a completely rational level because it is only pure language, with no personal interaction. Additionally, on-line communication results in a reduced understanding of relationships with others. Communication through computers relies on a disembodied view of intelligence and communication by lacking any form of personal interaction. Furthermore, such a view tends to favor men over women.

4.4 Off-line Communities for Women

On-line communities are extremely important in terms of improving the computer science environment and ultimately increasing the number of women within the field. However, since they rely on disembodied interaction, they also have their problems, as mentioned in section 4.3. Therefore, there is also a need for off-line communities for women that rely on personal interaction. Off-line communities for women in the field of computer science are very similar to their on-line counterparts. Off-line groups are women within the computer science field who join together to meet face-to-face on a regular basis in order to discuss the issues confronting them. However, most of the activities of off-line groups are done off-line; that is, without the use of a computer. It is interesting to note that most off-line communities for women within the field of computer science are spin-offs of larger, on-line communities, such as SWE [Society of Women Engineers]. Off-line communities have meetings at lunch time or in the evenings in order to discuss the problems which women computer scientists face. In addition, off-line groups plan trips to relevant conferences, as well as planning conferences themselves. For example, one successful women's off-line group describes its creation as follows:

> GM's [General Motor's] PWN [Professional Women's Group] began at a Society of Women Engineers (SWE) conference... Three years ago, thir-

teen GM women were attending a SWE conference in Chicago. They were having such a good time that they decided not to wait for the next SWE meeting to get together again.

Back at headquarters they set up a dinner meeting. Each of the thirteen would bring one or two guests she thought might be interested... The dinner was such a hit that the women began meeting regularly on their lunch hour... The group... now has a membership of approximately 600, who all enjoy the benefits of its mentoring programs and panel discussions" [25, p. 2].

Off-line communities of women within the computer science field are beneficial for women who want to connect in person. Meeting in person on a daily or weekly basis can help to show a woman computer scientist that there are other women in the computer science environment who share similar issues. Such groups are also beneficial to instituting change directly within the company or institution.

4.4.1 The Intersection of On-line and Off-line Communities

It is important to note the intersection of on- and off-line communities founded for women within the field of computer science. Off-line communities offer the close personal interactions that on-line groups do not have. On the other hand, such off-line communities also use computing means such as email to send out messages, and plan meetings and conferences. Thus, off-line communities for women computer scientists are frequently spawned from on-line groups. Women are brought together through the technology offered by email and other computing resources into large, geographically diverse groups. These groups may meet in person once a year or so at conferences. Eventually, women may form more personal groups that meet off-line to discuss the issues face-to-face. Women computer scientists are comfortable using computer technology to unite women within the field. However, many women also benefit from meeting in person and discussing issues in a close-knit group.

In addition, while on-line communities unite women from all different parts of the world, it may still be beneficial to unite women locally. Women computer scientists may have many things in common with individuals from different cultures, but they may still need to meet in person with others from their own culture to discuss more specific issues. On the other hand, after meeting locally and in person, women can go on-line to discuss issues further on a global scale.

4.5 Email-based Mentoring

The shortage of mentors that many women computer scientists face was discussed in sections 2.6 and 3.3. Email-based mentoring incorporates the idea that email can be used in order to bring together mentors and protégés. A number of programs have been initiated that use email in order to form mentoring pairs. For instance, one program states: "We pair women who are studying engineering or science at one of our participating universities with professional scientists and engineers working in industry, and help them form e-mail based mentoring relationships" [46, p. 1]. This type of mentoring has a number of advantages over traditional mentoring.

One advantage that email-based mentoring has is that many of the barriers standard mentoring faces are overcome by using the technology of email. MentorNet, an email-based mentoring program, thrives on the fact that, "using e-mail allows MentorNet program participants to transcend constraints of geography, time, and synchronous communication" [46, p. 1]. Mentors can be paired with protégés from across the nation or across the world using email, and still maintain the close relationship that is essential to a mentoring pair. In addition, protégés with email-based mentors do not have the associated problems of getting in touch with their mentors that protégés in a traditional mentor relationship must face. Dealing with phone conversations or making appointments to fit into their mentors' busy schedules is no longer required.

Another advantage that email-based mentoring provides is the chance for both mentors and protégés to speak their minds, and ask sincere questions or offer the best form of advice or criticism. Individuals are often more honest through email than they would be in person. In addition, mentors can offer the best advice by thinking matters over thoroughly, rather than having to answer immediately. Students also have the ability to go back over the advice that was given to them; the information that is exchanged between the mentor pair becomes more valuable if it can be maintained longer, and email provides this facility.

> "Students often feel less intimidated or hesitant asking questions using e-mail than they might posing those same questions in person or over the phone. E-mail also makes it easy to communicate thoughtfully and deliberately, and provides a record of communication. Students can refer to their mentors' past advice whenever they feel a need, and mentors can easily keep track of students' concerns" [46, p. 1].

However, it should also be noted that the honest form of communication that email offers has its drawbacks. Many individuals feel more inclined to "flame" or otherwise behave rudely through email, much more so than they would in person. This type of negative communication could hurt both the mentor and the protégé, and should be discouraged.

Email-based mentoring programs also offer the benefit of more diverse and better matched pairing. For example, pairing all students with possible mentors within a single institution does not lead to a very diverse set of matches. As was discussed in section 2.6, women faculty within the field of computer science are in a very small minority. Successfully matching students with mentors from a small pool such as that found in a single university can be very challenging. It is possible that the best mentor for an individual may be in another institution, or in another area of the country. Pairing individuals through email rather than pairing for face-to-face mentoring can offer the best mentor-protégé relationship for each individual.

In addition, the majority of computer science students, on the completion of their degree, go on to work in industry rather than continuing on in the academic field. However, most of the face-to-face mentors that are provided at academic institutions are mentors from academia. A student planning on entering into a career as an engineer is most likely to have a member of faculty as his or her mentor; that mentor is probably unable to provide all of the knowledge that the student needs in order to successfully enter industry. Email-based mentoring can help to pair students with mentors from the industrial community as well, providing a better match for an individual's ultimate goal.

> "Most engineering and science students ultimately find employment in industry, but on college campuses, the primary mentors available are those in the academic profession. Making students aware of post-graduate opportunities in industry encourages them to persist in science and engineering programs" [46, p. 1].

Providing students with mentors from the industrial field of computer science may better prepare them for their future career, as well as encourage them to continue within the field of computer science. For these reasons, email-based mentoring is especially relevant in retaining women within the field of computer science. As was mentioned in section 2.6, women studying and working in the computer science field tend to be more satisfied with women mentors. However, because of the under-representation at higher levels within the field, it is not always feasible for women to have mentors who are also mentors. This is especially true within academia, since there are fewer women faculty than there are women engineers working in industry. Providing email-based mentoring programs that match women in industry with women students can help to ameliorate this problem. Women computer science students will have a larger pool of women mentors when the students are matched with professionals from both academia and industry.

Notably, on-line communities, as discussed in section 4.2, can be a boon to email-based mentoring programs. Communities such as Systers can serve to unite mentoring pairs through their networking abilities. On-line communities are an important means of bringing women computer scientists together at many levels, and email-based mentoring is a very positive aspect of this type of networking.

4.6 Internet Repositories

It is difficult to find information on women in computer science. The information is not located in one type of resource, such as a single topic in a library, or under a single general heading in an Internet search tool, since the subject of women in the technical field of computer science is not a single field in itself. Similarly, the topic of women in computer science spans more than one discipline, including women's studies and computer science and engineering. Researching the topic of women in computer science is not an easy task. It would be very beneficial to have a single clearinghouse of information on the subject. Individuals could research in one area to find out large amounts of widely ranging information, from statistics on the number of women in the field, to specific problems that women computer scientists face, and proposed or practicing programs that help in attaining and retaining women in the field. It is important to acknowledge the lack of an organized collection of information on such an important topic within the field of computer science. One study notes that:

- "There is no efficient clearinghouse for those concerned about this issue.
  - Information is scattered and hard to find.
  - Very little comparative data on programs and techniques is easily available.
- There are no flexible communication links for business people, academics, program administrators or students to connect with individuals or groups around these issues.
- There is no mechanism for making sure that the best, most up-to-date information is available" [21, p. 1].

The introduction of such a clearinghouse of information using technology available through the Internet would be a strong boon to the field, while helping to solve the problem of the scarcity of women within the computer science field. The idea is to provide an Internet resource that would serve as an "up-to-date, universally accessible virtual repository of information about existing and effective programs for the recruitment and retention of women and under-represented minorities from elementary through professional life" [21, p. 1]. There are many data archives and repositories currently available through access to the Internet. Developing a single resource on the topic of women in computer science would be a valuable tool. One suggestion follows:

> "We are proposing the creation of a sustainable Internet-based national resource — ultimately as significant to the national economy as the Library of Congress or the Smithsonian are to the national intellect — that will ensure a vital and competitive science and engineering workforce in the coming century" [21, p. 2].

There are a number of efforts being made in the hopes of instituting standard Internet repositories on the topic of women in computer science. One study suggests the need to:

> "Make official information accessible to existing citizen's networks; offer infrastructural facilities to initiatives that develop data banks, on-line information services, Internet resources, etc. on these issues; and...that women's organizations and NGOs participate in collective endeavors to pool information and make it available electronically in different languages" [29].

Providing such a tool would require some initial effort as well as maintenance. However, the technology exists to provide a single resource using the Internet which would serve as a link to large amounts of diverse information on women in computer science. An Internet repository such as this would have many advantages for women within the field. In addition, an Internet repository providing data on women in computer science can be a valuable tool for encouraging women to enter the field. Successful programs for attaining and retaining women computer scientists can be documented, and new programs can be initiated using that information. In addition, women computer scientists could easily find information on issues that they are concerned about. A single clearinghouse of information on women in computer science through the means of an Internet repository could become a valuable resource for solving the problem of the scarcity of women within the field of computer science. After the acceptance of this thesis, I plan on providing an Internet site that can serve as a jumping-off point for research in the area; it shall include a link to this paper, as well as links to the references used herein, and communities such as Systers.

4.7 Remote Access

One possible solution to a number of the problems mentioned in the studies suggests providing women with remote access to computers, whether it be in the dormitory for a student, or in the home of a woman in industry. Offering remote access to computer resources for women solves both the problem of physical safety as mentioned in section 2.7.1, as well as some of the problems of family responsibility, as covered in section 2.5.

In terms of physical safety, remote access to computer resources solves the problem of traveling between the lab or the office and home at late hours of the night. Women can then go home at sensible hours of the evening, or travel when it is convenient, with a friend or colleague, and continue their work from home or from the dormitory. They will no longer need to sacrifice required working or studying time in order to avoid the dangers of traveling alone late at night.

Providing women with access to computers from the home also solves some of the problems of family responsibility. Women may need to be home at certain hours of the day in order to take care of the children, or support the family as needed otherwise. Providing women with computing facilities in the home gives them the opportunity to complete work at these times, where it would not be possible without access to office resources.

However, providing women with access to computing facilities from the home or from the dormitory also carries a price. Encouraging women to work from the home or dorm has the "disadvantage of isolating students" and isolating engineers from their peers [59, p. 1]. However, interaction with other computer scientists is one of the keys to success in both academia and industry, and a necessity for women to feel comfortable within the environment. As mentioned in sections 2.3 and 2.4.4, isolating women computer scientists can only perpetuate the problem of making them feel out of place in both academia and industry; in addition, it enforces the image of the computing environment as hostile.

Furthermore, providing remote access to office resources or to computing facilities is not always entirely feasible. From the home, a woman may be depending on a dialup service, which most likely will not suffice for all of her computing needs. Alternatively, a remote connection from a dormitory may have an additional Ethernet connection. However, the same problem still exists since even Ethernet connections cannot be used for computationally intensive work; women who live off campus are then also at a disadvantage.

However, remote access may also offer women computer scientists another important benefit. That is, remote access can provide women access to on-line communities and other networks and Internet sites form the home, outside of the professional working or academic environment. This can help to offer women the opportunity to discuss the issues that women computer scientists face from outside of the actual environment, in a location such as their home where they may feel more comfortable discussing serious issues such as sexual harassment and the glass ceiling.

Chapter 5

Conclusion

In order for the computer science field to achieve its maximum potential, more women must be encouraged to enter and remain in the field. However, there is no single panacea to this problem. In order to increase the number of women within the computer science field, efforts must be made both within the field itself as well as in society as a whole.

Women computer scientists face a number of issues as members of a small minority in a male-dominated field. These issues must be recognized as serious problems and dealt with accordingly. A serious analysis of possible solutions to these problems was covered in Chapter 3 of this thesis, and is an important step in addressing the issue. In addition, programs must be instituted to attract more women to the field.

Computer technology itself can be used to attain and retain women within the computer science field. The benefits that computer-mediated communication provide can be taken advantage of to both attract women to the field, and encourage them to stay. Internet repositories can be utilized to gather information about women in computer science, and to make the retrieval of such information efficient.

Most importantly, increasing the number of women in the computer science field must be accomplished actively and assertively. Acknowledging the problem is the easy task. In addition, women themselves must be the instruments of change in order to accomplish such a feat. Discussing the issues that women computer scientists face is an important part of solution, but merely the first step. Women must also make an initiative to successfully institute programs that aim to encourage more women to enter the computer science field. Alerting others to the problems within the field that result in few numbers of women computer scientists should result in others improving their attitudes toward women computer scientists, and additionally improving the environment of computer science institutions. However, women themselves must actively use computer technology in order to improve the computer science environment, and ultimately increase the number of women within the computer science field. If women only depend on the standard solutions that were covered in Chapter 3 of this thesis, they will be submitting themselves to the traditional passive role that women have historically remained in. Women must actively make an effort to improve the computer science environment, utilizing the recommendations made in Chapter 4 of this thesis. Women must unite through on-line communities, and promote an environment that will attract both men and women to the computer science field.

> "One wonders how many ideas, that could have been contributed by female talent, will never surface to enrich academic computer science. More broadly, what are the repercussions to our increasingly computer-oriented society, if women — about half the population and professional workforce — are not as prepared in this discipline as are men? Perhaps we will not have to find out" [32, p. 45].

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