

**Investigating the Incredible Shrinking Pipeline  
for Women in Computer Science**

**Final Report – NSF Project 9812016**

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## Introduction

The pipeline shrinkage problem for women in science is a well known and documented phenomenon. It is particularly evident in the computer science (CS) fields where the ratio of women to men involved in computing from high school to graduate school shrinks dramatically. Furthermore, while the percentage of bachelor's degrees awarded in CS to women decreased almost every year over the last decade, the corresponding percentages of other science and engineering disciplines increased. Since the number of women at the bachelor's level affects the number of women at levels higher in the pipeline and in the job market, these facts are of great concern to both the computing community and the National Science Foundation (NSF).

During the last decade, considerable research has been undertaken to understand the reasons behind the existence of the incredible shrinking pipeline and in some cases to take action to increase the numbers of women in computing. However, there has not been a central focus to bring all this research together and thus help provide a coherent direction for future work. Through the work of this NSF funded project, we have taken a first step towards this goal. A large number of articles was gathered and processed on the topic of women in computing and the shrinking pipeline. A publicly available on-line database was created to organize the references of this body of work by topic, author, and reference information (e.g., date, journal, volume, pages etc.) In addition, this report was written to summarize much of the information that is contained in the database (as of August 2001).

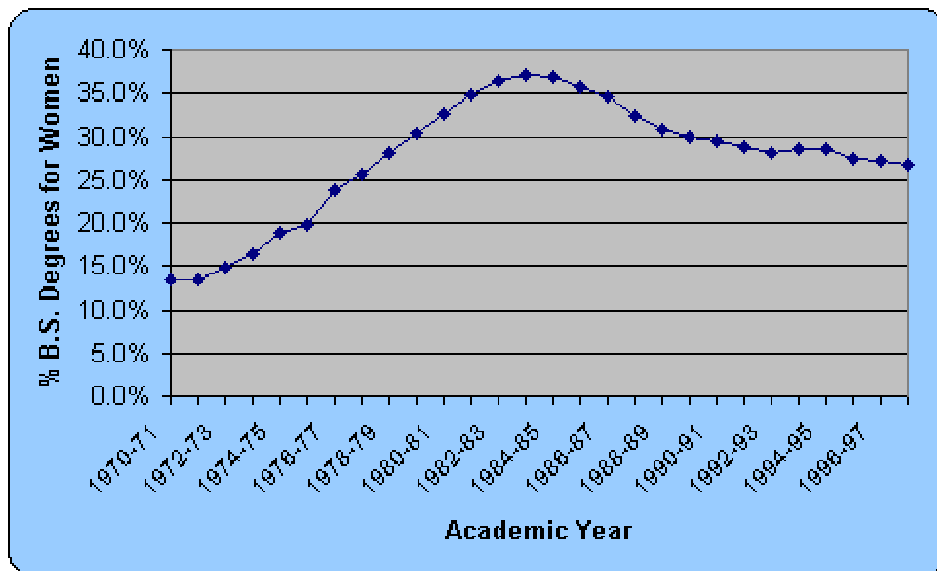
Women in computing is an active area of research and a popular topic in the public media. Thus, many new articles and websites will be created and published. These will need to be added to the pipeline database to keep it up to date. This is crucial, since an outdated database is not very useful for current researchers and other people interested in this topic. Thus it is the intention of ACM-W (The Association of Computing's Committee on Women in Computing) to continue to maintain this database as long as possible. ACM-W has made the database available via its website (<http://www.acm.org/women>) along with the means for additional references to be submitted on-line through e-mail. Resources within ACM-W will be earmarked for processing these reference requests and for keeping the database up to date.

It is our hope that the end results of this project will achieve three outcomes:

- Provide a public repository and central focal point for information and research pertaining to women in computing,
- Raise the consciousness of the computing community through the web site and dissemination of the final report, and
- Suggest directions to move towards to help increase the numbers of women in computing and make computer science environments more women friendly.

## The Shrinking Pipeline

The pipeline shrinkage problem concerning women in computer science is a well known phenomenon (Camp, 1997). Although women make up 50% of high school CS classes (Walker & Rodger, 1996), the percentage of bachelor's degrees in CS awarded to women in the 1997-98 academic year was only 26.7% (NCES, 2000)<sup>1</sup>. As Figure 1 illustrates, this is a decline from a maximum of 37.1% in the 1983-84 academic year to 26.7% in 1997-98. For the same academic year, the percentages are 29.0% at the M.S. level and 16.3% at the Ph.D. level. Not surprisingly the pipeline also shrinks through the academic ranks. According to the CRA Taulbee Survey, only 14% assistant professors, 13% associate professors, and 8% full professors were women in CS Ph.D.-granting departments during the academic year 2000-2001 (Bryant & Irwin, 2001).



**Figure 1:** Percent of B.S. degrees awarded to women from 1970-1998. Data from (NCES, 2000).

Not only are the percentages low, but over the past fifteen years (1983-1998), we have witnessed a rapid decline of women graduating with bachelor degrees in computer science<sup>2</sup>, moving from 37.1% to 26.7%, giving an alarming 28.0% decrease. The decreasing percentages of female computer science graduates is especially discouraging when other fields and factors are considered and it becomes clear that women are excelling elsewhere.

### Enrollment

In 1998, more women than men (aged 25 to 29) graduated from high school: 90 percent of women compared to 87 percent of men (NSF, 2000). This is a reversal from

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<sup>1</sup>These are the most recent statistics from the National Center for Education Statistics.

<sup>2</sup> All statistics cited in this report correspond to the United States of America. However, similar analogies can be drawn for most other industrialized countries. Some statistics for other countries can be found at the ACM-W web site: [www.acm.org/women](http://www.acm.org/women) via the Ambassador Program.

1980 where the educational attainment of men was higher than women. At the university level, the current rate of enrollment for women is higher than for men. Between 1988 and 1998 for all types of fields: women's rate of enrollment increased by 16 percent, while men's rate only increased by 6 percent. In 1998, the number of women enrolled in graduate school exceeded that of men with 55 percent of graduate students in all fields being women. From 1988 to 1998, the rate of increase was much higher for women: 60 percent for full-time women and only 17 percent for full-time men, and an increase of 17 percent for part-time women and only 2 percent for part-time men (NCES, 2000).

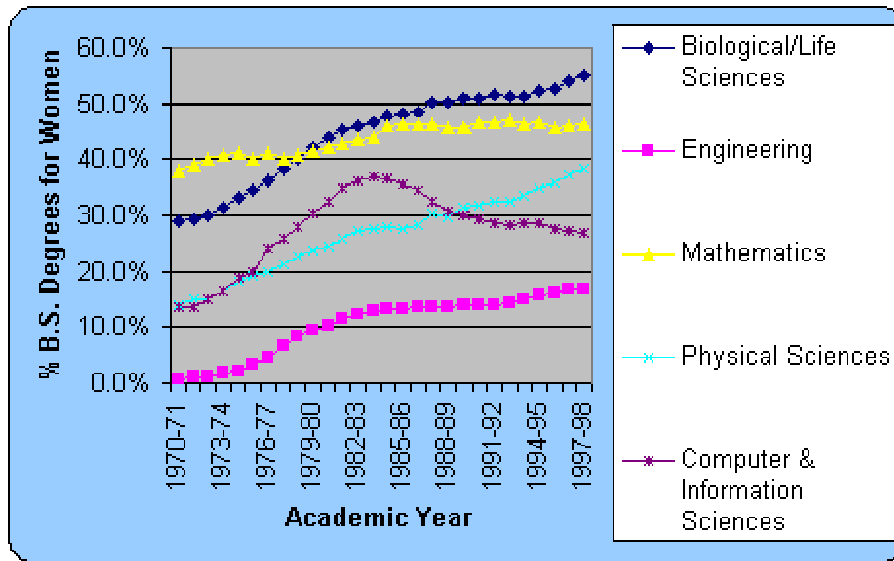
An examination of the distribution of where women and men are enrolled, results in equal representation. A little less than half of both women and men are enrolled in 2-year institutions, about one-fifth are enrolled in master's granting institutions, and a little more than one-tenth in the Nation's top institutions (NSF, 2000). Additionally, women and men are equally likely to graduate from college with 32 percent of women and 30 percent of men aged 25 to 29, earning a bachelors degree in 1998 (NSF, 2000). However, the rate of increase is higher for women than for men: 28 percent for women and 9 percent for men (NCES, 2000).

### Degrees Earned

If one looks specifically at math and science, as shown in Table 1 and Figure 2, the percentages of B.A./B.S. degrees awarded to women has increased (1983-1998) for all fields except computer science: 17.7% for biological/life sciences, 32.0% for engineering, 5.9% for mathematics, and 39.1% for physical sciences. The percentage of women receiving degrees in engineering is still less than computer science, however, the gap is rapidly narrowing.

Field	Percent B.S. Degrees Awarded to Women 1983-1984	Percent B.S. Degrees Awarded to Women 1997-1998	Percent Gain/Loss
Biological/Life Sciences	46.8	55.1	+17.7
Engineering	12.8	16.9	+32.0
Mathematics	43.9	46.5	+5.9
Physical Sciences	27.6	38.4	+39.1
Computer & Information Sciences	37.1	26.7	-28.0

**Table 1:** Percentages of B.S. Degrees Awarded to Women in all Sciences. Data taken from (NCES, 2000)



**Figure 2:** Percent of B.S. Degrees Awarded to Women 1970-1998. Data from (NCES 2000)<sup>3</sup>

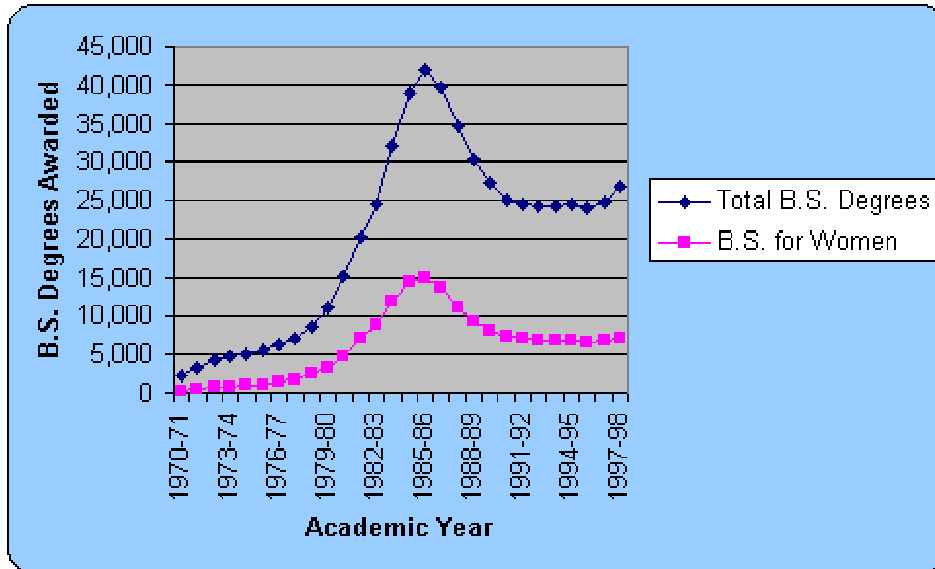
As the graph in Figure 3 shows, the number of women receiving B.S. degrees in computer science was at a high in the 1985-86 academic year. This corresponds to a high in the percentage of women receiving B.S. degrees (37.1% in 1983-84). The total B.S. degrees dropped dramatically from 1985-86 to 1990-91 and is now increasing (an 8.4% increase from 1996-97 to 1998-99). A reasonable assumption is that the numbers of women receiving B.S. degrees and the percentage of B.S. degrees awarded to women will increase, as they have in the past. However, current research indicates that this is not the case<sup>4</sup>. An examination of the current enrollment and computer science major declarations at universities on the CRA Forsythe list, do show a small increase in the number of women receiving B.S. degrees in computer science. However, they also show a steady decrease in the percentages of women receiving B.S. degrees in computer science (Camp, Miller, & Davies, 1999; Davies & Camp, 2000).

Another concern is the numbers of women graduating with graduate degrees. The percentage of women receiving M.S. degrees has exceeded that of the B.S. degrees in the 1997-98 academic year and appear to have plateaued around 28.4%. Even so, if the current percentages of B.S. degrees is decreasing, this implies a decrease in M.S. degrees a few years down the road due to fewer women in the pipeline. On the other hand, the percentage of Ph.D. degrees appears to be rising steadily, independent of the rise and fall of the numbers of M.S. and B.S. degrees. This is likely due to the fact that the numbers

<sup>3</sup>According to NCES, biological/life sciences includes biology, biochemistry, biophysics, botany, cell and molecular biology, microbiology/bacteriology, and zoology; engineering includes engineering, construction trades, and mechanics and repairers; mathematics includes mathematics and statistics; physical sciences includes physical sciences, astronomy, astrophysics, atmospheric science, meteorology, chemistry, geology, physics, and science technologies, and computer and information sciences includes computer science, information science and systems, computer programming, data processing technology/technician, and computer systems analysis.

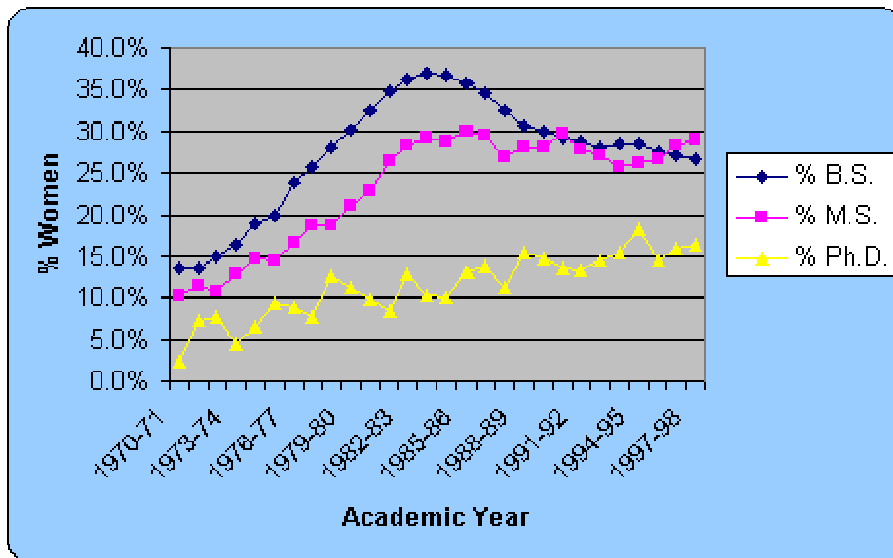
<sup>4</sup>This research was sponsored by ACM-W and the results can be found at <http://www.acm.org/women>

of women graduating with Ph.D.s are so small and the difficulty and time factors are more extensive. In other words, the B.S. and M.S. degrees may be more susceptible to external forces such as the economy and popularity issues for the field of computer science.



**Figure 3:** The number of B.S. degrees awarded, total (men and women) and for women only, 1970-1998. Data taken from (NCES, 2000).

**Figure 4:** A comparison of the percentage of women receiving B.S., M.S., and Ph.D. degrees in



computer science. Data taken from (NCES, 2000).

### Why Worry?

There are a number of reasons why we as a nation should be concerned with these declining numbers and work towards increasing the percentage of degrees awarded in CS to women. One compelling reason is there is a critical labor shortage in CS and, although women are more than half the population, they are a significantly underrepresented

percentage of the population earning CS degrees (Pearl et.al., 1990). Information technology (IT) industries now account for a large portion of the U.S. economy and a key source of IT workers are students graduating with degrees in CS. According to an ITAA study (ITAA, 1998), there are nearly 346,000 unfilled IT positions in the United States, representing a 10 percent vacancy rate. It will only get worse as the Bureau of Labor Statistics predicts that the demand for workers in the IT field will grow to over one million additional IT workers between 1994 and 2005. Thus, more workers must be trained for the IT industry. Women comprise fifty two percent of the population and serve as a critical largely untapped source of intelligent, creative, and productive people for the IT industry.

A consequence of the worker shortage is the pull of CS professionals away from academe due to the lure of higher salaries and the fast pace of start-up companies. This movement has been described as a “seed-corn” problem (Freeman & Aspray, 1999) where the U.S. is losing the core of its ability to train new IT workers, at a time when demand for CS workers and enrollment for CS is on the rise. On average, CS departments want to grow by 21% over the next two years and the production of new Ph.D.s (men and women) will not cover this demand (Bryant & Irwin, 2001). To make matters worse, demographic trends indicate that the numbers of new Ph.D.s going into academe will decline due to the increasing number of nonresident U.S. citizens graduating with CS Ph.Ds.

Another issue is the pervasiveness of computing in our society. Ideally we want technologies to benefit all members of society and we want technology to be available to everyone regardless of gender, race, or economic standing. “People who come to science from different locations, be it because of gender or race or class, tend to ask different questions rather than accepting the mainstream assumptions.” (Thom, 2001, p. 103) In order to meet the demands of the future, creative intelligent solutions must be developed. In order to meet this goal, all members of society must partake in IT in all areas such as research, design, manufacture, sales, and education. Again, women comprise fifty two percent of the population and should be represented equally in all aspects of IT. Having equal membership in computing will benefit individuals (since IT represents well paying jobs) and will aid in producing useful and creative technology for all of society.

## **The Big Questions**

The underrepresentation of women in computing is alarming since it raises the disturbing possibility that the field of computer science functions in ways that hinder or discourage women from becoming a part of it. It is imperative that we encourage and retain more women in computing. This begets the questions: Why are the numbers going down? and How can we reverse this trend?

This project has taken a modest step towards answering these questions. First we describe the pipeline database created with this project that contains references related to the incredibly shrinking pipeline for women in computer science. Following that is a group of summaries of the work represented by these references. We divided the summaries into 14 areas that we felt best categorized the work:

1. **Attitudes** –Positive attitudes can greatly influence the success of a student and whether they continue in CS. Attitudes towards computers and their

uses differ along gender lines where more boys are positive and more girls negative towards computing.

2. **Computing Experience** – Experience plays a key role in how well students do in college level computing classes. Boys obtain more pre-college experience than girls.
3. **Early in the Pipeline** – Girls lose interest in computer science early on. From as early as preschool, female students need to be encouraged to engage with computers.
4. **Computer Games** – In many cases the first experience girls have with computers is through computer games. However, today's games are designed for boys' interests and not girls. This is an early turn off for girls for CS.
5. **Mentoring and Role Models** – Mentors and role models help in the recruitment and retention of women in CS.
6. **Self-Confidence** – Loss of self-confidence impacts women more than men and is a major cause for women leaving CS at all levels in the pipeline.
7. **Computing Environments** – Many computing environments in educational settings and industry are hostile towards women.
8. **Family and Teacher Encouragement** – Family and teachers can play an important role attracting and retaining women in CS.
9. **All-Female Environment** – Environments that only allow female students can produce women with higher levels of confidence in math, science, and engineering. This in turn translates into career success and potentially increasing the pipeline for women in CS.
10. **Equal Access** – Girls need equal access to computer usage in K-12 schools. In many cases boys dominate a computing lab and the girls do not get the same exposure to computers.
11. **Graduate School** – The pipeline shrinks dramatically from undergraduate to graduate school. Female graduate students must be recruited and retained.
12. **Balancing Work and Family** – Many women drop out of CS when they have children due to the inflexible demands of the workforce. This is especially true in academia where the time a woman is seeking tenure is also the time she is contemplating having children.
13. **Societal Influence** – Society has a profound impact on young girls' images of themselves and computer science. Unfortunately most of the images of CS coming from parents, teachers, and the media are all negative and imply that computing is for men only.
14. **Other Forms of Discrimination** – Three forms of discrimination that do not fit into the above categories, contribute to keeping women out of CS:



subtle but constant discrimination, the invisibility syndrome, and hiring to keep women down.

This document concludes with a set of suggestions culled from this work and other documented sources. It is our hope that these suggestions will aid our society in moving towards more equal representation of women in computing.

## **Pipeline Database**

The Pipeline Database compiles references and HTML hyperlinks (when applicable) to articles and documents pertaining to women in computing and the shrinking pipeline. Articles included document gender issues and differences related to women in computing with a focus on why we are losing women in the CS field and what we can do to reverse that trend. Information for each reference includes the author(s) of the article, the journal, book or magazine it was published in, and when it was published. Also included are several keywords or phrases that are used to further describe the contents or subject of the article to aid in searches. The database is the result of research where articles were hand gathered, catalogued, and input. The search engine queries the database only in order to find relevant articles. In other words, it does not access any external web sites or web search engines to return results. Thus future additions to the database must be made by hand. As stated previously, ACM-W has made provisions to handle this work.

### **Internal Technology**

The Pipeline Database uses a MySQL engine, which is free and extremely fast and light-weight. MySQL does not support transactions or many functions that commercial database programs would handle. However, MySQL is more than adequate for this application. A search engine is employed with the front end written in HTML and PHP. PHP is a scripting language which allows the easy creation of dynamic web sites with changing content. It also has database connectivity functionality, so the match between PHP and MySQL is nearly seamless. In addition both PHP and MySQL can run on many different platforms including Linux and Windows.

The content portion of the database consists of one main table for each article. Each table contains all information about its article, including all authors, keywords and any other relevant information pertaining to the article, such as volume, number, page, and year. There are also two other semi-temporary tables which speed up the listing of authors and keywords when requested by the user. To this end, they hold a list of all the authors and keywords found in the main table.

Currently (as of August 2001) the database contains 276 records representing 276 articles. There are 329 unique authors represented and 100 unique keywords. The current implementation and database design limits the number of authors per article to only four authors, and the keywords to only five keywords. Note that normalization of the database would remove these limits and allow for a potentially unlimited number of authors and keywords per article and it would remove the need for the temporary tables. However, this is a task for future work and/or funding.

## User Interfaces

The search engine contains two interfaces. The first is the public interface, shown in Figure 5, which allows searching based on first or last name of the author, journal, publisher, year, title, or keyword. Phonetic matching is allowed for first or last name which allows a misspelled entry to find the desired articles even if the user is unsure of the spelling. For instance, a search for "Jon" would return articles in which the first name was "Jon", "John", "Joan", "Jane", "Jen", or any other first name that sounded like "Jon" and begins with a "J". Instead of entering a name or keyword, the user can also click on the name or keyword provided in complete keyword, author and journal lists.

The second interface is the administrative interface. In addition to all of the previously mentioned capabilities, it also allows a search by record ID. This gives an administrator the ability to jump directly to a specific record without having to remember any uniquely identifying characteristics. Record ID is also displayed next to each record for easy recognition. This ID is hidden in the standard interface that would be seen by public web users.

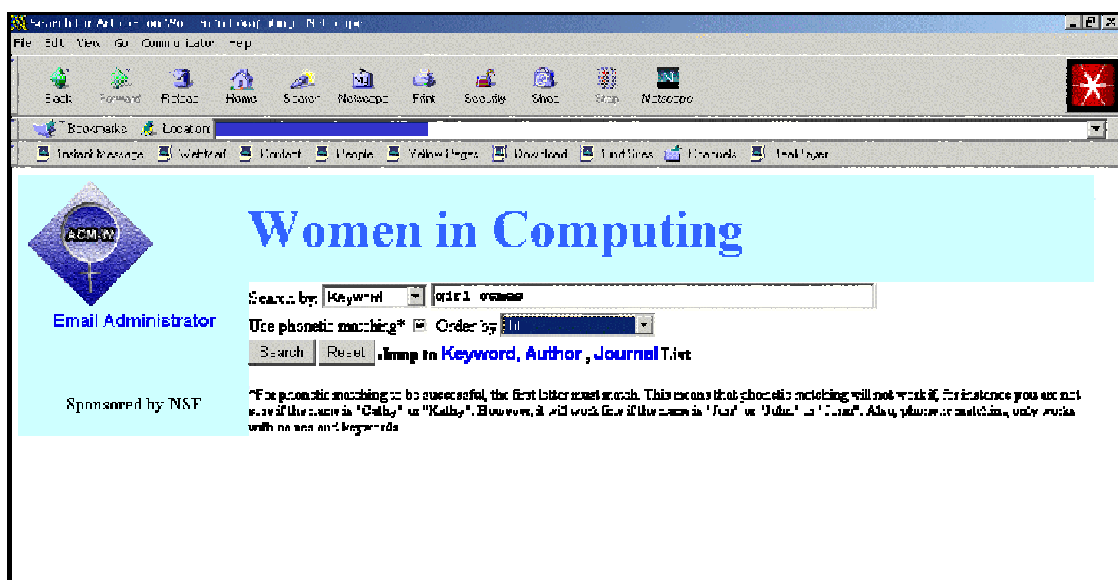


Figure 5: User interface to the search engine of the Pipeline Database.

The administrative interface allows the addition of new articles, editing or modifying of existing articles, and the deletion of articles. These three functions also result in the updating of the two temporary tables containing keyword and author lists, so these tables will remain current automatically.

## Future Database Work

There is room for improvement to the current implementation of the Pipeline Database. The following are recommendations that would make the search engine faster and allow for easier maintenance of the code.

- 1) **Normalize Database** – the original list of articles was contained in a spreadsheet, so the database was designed to minimize effort in converting from

spreadsheet to database. Thus there are four columns for the first and last name of the author and five columns for keywords contained in each record. This means that if any author name were to be misspelled, it would be counted as a new and unique name in the author list. Updating the database with a normalized database would mean only one change would need to be made in order to have the correction immediately show up on all records. Also, less space would be needed since authors and keywords would only be stored once for all records.

2) **Modernize Interface** – The interface and search results page could undergo a facelift which would allow for additional functionality. One could be sorting results by just clicking a header in the results. Another could be clicking any result would send you to a search page as if you had requested a search on that word or author.

3) **Separate Interface and Database** – Currently the interface is intermingled with the database code, causing any update to the look and feel a difficult and daunting task. Many of the API calls that are made are redundant and could be moved into a few functions. This would allow an administrator to maintain just a few functions rather than searching all of the pages each time a particular operation was done. Separating the code from the interface also allows the look and feel of the interface to be changed with ease.

4) **Allow Multiple Database Users** – The use of multiple database user accounts for the search engine would enhance security. For instance a user with no permissions besides SELECT would be able to search the database but do nothing else. This user profile could be used for the external public search site. This way, the user would be blocked from executing anything unwanted on the database, such as modifying or deleting records. User profiles with more permissions could be used to provide access to modify the database.

5) **Secure Administrative Interface** – Currently the administrative interface is not secure. There is no link to it from anywhere, but anyone who knows the URL of the administrative interface would have administrative access. Moving this to a protected site, or modifying it so that a username/password were required would greatly reduce the chances of an unauthorized user making harmful changes to the database.

6) **Additional Capabilities** – Additional capabilities could include allowing the upload and access of the entire article if permission were obtained from the author. Also, allowing the creation of user accounts so customized interfaces could be displayed. Customization could include changing the colors or look and feel, or even allowing certain users access rights to update the database. For example, authors could be given the ability to modify the entry for their articles. Additionally, users could submit articles to be included in the database. Ideally, the submissions would be reviewed by an administrator before actually being visible on the web site.

Users with or without accounts could potentially be able to leave comments regarding a particular article and engage in a threaded public discussion with other users about the article. These comments could be moderated and approved before inclusion on the public web site, or a user's post could be made immediately visible.

## Summaries

The references in the Pipeline Database were categorized and summarized (as of August 2001). The following contains summaries of these references divided into 14 different categories. One condition for a reference to be included in the database, was for it to represent a paper or article on a topic corresponding to the loss of the percentages of women in CS (i.e., the incredibly shrinking pipeline). An extensive search was performed for these references, however, we acknowledge that there are still some missing. This is why the pipeline database is an ongoing project within ACM-W where new references and even new categories will be added.

### Attitudes

A well researched area is the examination of computing attitudes for both males and females, producing varying results on how to achieve positive attitudes. There is agreement, however, on the importance of having a positive attitude towards computers from a very early age. This is essential for both genders if they are to pursue a CS career.

In general, the majority of studies have shown that the amount of experience a person has with computers greatly affects their attitude towards computer related activities. Those students who have computers at home or spend a considerable amount of their spare time in computer labs tend to have a more favorable view of computers than students of the same age with less exposure to computers (Corston & Coleman, 1996). Many studies revealed that experience with computers tends to promote interest. However, it's not clear whether an established interest in computers leads to higher levels of experience or more experience leads to more interest (Shashaani, 1993; Loyd & Gessard, 1984).

In looking at preschool and elementary level students, most seem to have positive attitudes towards computers without assuming any gender differences. It is not until later years that gender differences become pronounced. Thus, it is crucial that children at this young age are given equal exposure to computers and have positive experiences to carry through to their later years (Fletcher-Flinn & Suddendorf, 1996; Bernhard, 1992; Levin & Gordon, 1989). Teachers should be careful to ensure all students have equal time and opportunity with the computers and most importantly, ensure that students at such a young age have fun.

One approach to encouraging girls to enjoy computing and have positive experiences is to expose them to female CS instructors. Some studies show that both girls and boys work more efficiently and proficiently when someone of the same sex instructs them. Even those girls with little or no computing experience performed surprisingly well and reported positive attitudes when they were in the presence of a female instructor (Corston & Coleman, 1996).

### Computer Experience

To many, it seems intuitive to believe that as a person gains experience with a computer their level of confidence in using computers will increase. As a computer user encounters problems, develops methods to solve them, and eventually finishes their task successfully they should gain confidence in their own abilities to manipulate a computer. To this end, many studies have taken place in an attempt to prove and/or disprove this

idea. Unfortunately, for every study that supports the hypothesis that increased experience promotes computing confidence (Shashaani, 1994) another study refutes it (Broihier et. al., 1989).

In addition to confidence, experience plays an important role in the success of a student in college level CS courses. Some studies show that a large number of women students are entering first level computing courses at universities with less experience than their male colleagues. A study at SUNY Geneseo found that few women graduate from their computer science program due to a lack of pre-collegiate skills necessary for a successful completion. In addition, they found their male students had the needed pre-collegiate skills (Scragg & Smith, 1998).

Similarly, in an examination of students enrolled in the computer science programs at Princeton and Rutgers, the majority of female students lacked the computing skills needed for success. More specifically, those students who obtained knowledge of selection, looping, procedures, arrays, and pointers before entering college experienced greater levels of success than those who did not (Parelius & Sackowitz, 1996). Prior experience in computing was also found to help students who were not specifically interested in obtaining a computer science degree. Women in particular seemed to benefit from the most simplistic computing knowledge such as word processing, keyboarding and basic programming skills. (Mounfield & Taylor, 1994).

With this knowledge in hand, it seems reasonable to presume that educators should focus their attention on introducing female students to computer science studies as soon as possible. As young children, boys tend to gain computing experience on their own. Computer labs are commonly overwhelmed with the male presence just as male members of the family dominate home machines. This self-initiated experience provides young men with the opportunity to obtain basic, yet important knowledge.

One area of key impact is the fact that young boys are familiar with computer jargon. Young girls rarely find themselves in situations that introduce basic buzzwords that can be used as building blocks to more complicated computing concepts. As a result, Girl Scouts has created a web page specifically designed to introduce their participants to basic buzzwords such as Boolean algebra, domain name, host, Internet, lurker, network, protocol and virus (Girl Scouts, 1999). The hope is that this source of information will increase computing interest in young girls so they may be able to reach the same level of expertise as boys their same age.

Currently, girls fall behind their male counterparts by the time they reach high school. Between 1984 and 1996, men continuously outperformed women on the AP Computer Science Exams (Clancy et. al., 1988). Furthermore, the number of female students taking the AP CS Exams was small. Of the total population taking the AP exams during the twelve years studied, only 11- 15% of the AB test takers and 17-22% of the A test takers were female.

Boys/men not only obtain more experience than girls/women, but the type of experience they obtain differs greatly as well. Women tend to focus on their studies. They focus on concepts and skills that will help them obtain high marks in their classes. However, while women are striving to improve their grades men are busy “tinkering” with ideas that interest them. They obtain hands-on knowledge as they fix computers,

create interesting applications, and gain confidence in their abilities to apply their knowledge to real-world situations. Females then become concerned because their male counterparts seem to understand concepts and ideas that were never presented in class. In general, women have confidence in their ability to master the projects presented in class but feel inadequate when determining whether or not they will be able to successfully apply their knowledge to a real-world problem (CRA-DMP, 1999).

### ***Misleading Course Prerequisites***

Compounding the negative effects that a lack of computing experience and skills may have on female students, are the effects of misleading course prerequisites. In a recent study, it was found that even the most basic computing courses assume a certain level of knowledge that many female students have not yet obtained (Bernstein, 1997). Failing to understand basic buzzwords, feeling unfamiliar with machines other than those found at home, and ignoring the names of software packages used to run the computer, used to write papers, and used to access the Internet, prove harmful to women. The lack of confidence that many female students feel when encountering a computing environment is intensified when they have trouble succeeding in what is supposed to be the easiest computing course offered. It cannot be emphasized enough that this is due to a lack of pre-course skills or experience, and not a lack of ability or interest. The assumption of prerequisites only compounds this problem.

One approach is to make sure that instructors refrain from assuming any computer knowledge in introductory courses or by offering pre-introductory courses for those students who have absolutely no computing knowledge. Another approach is to survey introductory classes to ascertain the level of knowledge held by each student and then to teach accordingly and offer tutoring for those who need to “catch up”. Not only will the professor have a better idea of where the class stands as a whole but students will have a better idea of where they stand within the class (Bernstein, 1997).

## **Early in the Pipeline**

### ***Before High School***

It has often been observed that female students lose interest in computing by the time they reach high school (Stanley & Stumpf, 1997). Therefore, proactive interventions must take place as early as the preschool years. Girls need to obtain the experience necessary to have confidence in their computing skills before computing stereotypes set in. For example, boys and girls both tend to think that computing is a male domain. This attitude changes only when both sexes see, on a repeated basis, that their female classmates as well as female instructors can successfully use a computer (Bernhard, 1992). It is important to begin training as early as preschool to understand that gender differences do not have to exist when computing is in question (Fletcher-Flinn and Suddendorf, 1996).

Girls are taught from an early age that their role in life is to be docile, polite, and “lady-like.” These qualities can be counterproductive when young girls are required to compete with young boys inside computer labs as well as the typical classroom. While boys tend to “jump in” and explore computers without explicit permission during class, girls wait to be told what to do and often ask permission to explore the computer on their

own. The male tendency to jump in and explore without permission allows boys to increase their knowledge of computers to a degree that females are unable to attain (Bernhard, 1992). Furthermore, it has often been observed that boys tend to monopolize the instructor's time, leaving the girls to try and figure things out on their own (Huber and Scaglione, 1995). This imbalance can frustrate young girls, which in turn leaves them with a dislike of computing.

### ***High School Environment***

For those female students who managed to maintain an interest in computers during their earliest years of schooling, conditions often worsen when they reach high school. Women find themselves as a minority in computing courses. Many of their same-sex friends from elementary and middle school have voluntarily weeded themselves out (Alper, 1993). In addition, high school computing courses seldom prepare students to be successful in a collegiate setting. For example, they learn idiosyncratic and often inappropriate approaches to problems that deal with a single system or are given menial assignments such as changing a single print statement within a piece of code (Linn, 1985).

### **Computer Games**

Computer games are usually a child's first experience with computers. This introduction plays a large role in determining a child's future interest and enjoyment in using computers. Currently, most computer games are aimed at the boy market. These games encourage competition, shooting, violent graphics, and loud noises – most of which do not appeal to girls. Interestingly, it's the repetition of the music and game activities that girls do not like. In short, they get bored. Girls tend to prefer games that encourage collaboration with other players and involve storylines and character development (Graves & Klawe, 1999; Klawe, 1998).

Furthermore, in video arcades children are often subject to aggressive behaviors such as shouting and swearing which is also offensive to young girls (Kolata, 1984; McCormick & McCormick, 1991; Kiesler et. al., 1985). Rarely do young women visit arcades in order to play video games. Instead, they visit arcades in order to meet young men or to watch their boyfriends play games.

It has been found that children who play video games, acquire more experience using computers and are more likely participate in a high school computer class. Thus, more care should be taken in creating girl-friendly games (McCormick & McCormick, 1991). Games like Pac-Man and Ms. Pac-Man seemed to help change the general atmosphere by successfully capturing the attention of girls (Sproull & Eccles, 1983), however, the more recent games make no attempt to attract girls.

### ***Profits Ignored***

Until recently, software manufacturers have ignored the female population. This seems unusual considering the amount of money little girls spend on various sources of entertainment. In fact, adolescent girls typically spend more money than their male counterparts (Chaika, 2000). Since video games are not targeted at females, girls tend to spend their money on other sources of entertainment such as magazines, clothes, movies, books and fashion. In November 1996 Barbie and her young female fans took the

software industry by surprise when Mattel introduced its software hit *Barbie Fashion Designer*. Although many feminists hate the thought of promoting Barbie and her superficial persona, the game gets girls in front of a computer and allows them the opportunity to see that computers can be entertaining. Mattel sold over 200,000 copies of their Barbie game within the first month of release and in the last two months of 1996 retailers made \$11.5 million from the fashion software (Gorriz & Medina, 1997; 2000). Barbie sold over 1 million copies, ranking it with the most popular male games such as Duke Nukem, Diablo, and Warcraft II (Angwin, 1997). Several companies jumped on the bandwagon and attempted to make games marketed to girls (Beato, 1997).

Creating software games for girls is not as easy as it sounds. Gender biases exist among software designers which prevent them from making games that girls will really enjoy. Many girl games on the market tend to create games that focus on shopping or putting on makeup, rather than the interactive storytelling or educational games that girls crave. In addition, creating an interactive storytelling game is potentially more technically difficult than a standard shoot 'em up game.

In a study by Huff and Cooper, it was found that software designers do exhibit gender biases. Software designers were asked to create a piece of software for seventh-grade boys and another for seventh graders in general (Huff & Cooper, 1987). Designers consisted of educational professionals at all grade levels and of both sexes, although many more women than men participated. Both designs were similar in that they were game oriented, required eye-hand coordination, quick reflexes and a sizeable amount of action on the screen. When the same group of software designers was asked to create software for seventh-grade girls, their focus changed considerably. This time, their final product served as an educational tool rather than a source of pure entertainment. While this is disconcerting in that females are not given the opportunity to experience computers as a source of entertainment, this mentality can be justly upheld. Even as small children, boys and girls tend to create games with different approaches. While boys tend to kill or destroy characters in their games, girls tend to penalize them but allow the character another chance. In addition, girls often enjoy educational games more so than boys.

### ***Imagery Aimed at Boys***

A quick inspection of video games reveal that not only are most games targeted at young boys in the content of the game but it is a rare occasion to see females on the covers of video games as well. Even worse, the few women who are incorporated into video game covers are usually in submissive roles portraying a fearful and almost helpless creature, while the males stand in dominant poses (Chaika, 2000). Research has noted that girls like to see female characters in games that are powerful and strong instead of cowering beside an evil character waiting to be rescued by her prince (Gillen, 1994).

Imagery in a game plays more of a role than game makers may realize. A study conducted by Bournemouth University (BBC News, 2000) found that when children were asked to solve a reasoning problem, their results differed depending on the wording and imagery of the problem. When kings, pirates, and mechanical forms of transportation such as planes and ships were used, the boys outscored the girls. However, when the



problem was re-written to include 'honeybears', a pony, and balloons the girls outscored the boys. Similar results were found in (Johnson & Swoope, 1987).

It should be noted that technology in its earliest years of computer games may have forced programmers to leave out imagery textures desired by girls, including changing images and colors (Fryer, 1994). The earliest game cartridges with limited space failed to hold large amounts of data needed to provide these graphic details. However, with current technologies, lack of storage fails to be an issue.

### ***Girls vs. Boys Toys***

To further enhance the problem, industry has adopted the idea that girls will play with boys' toys but boys won't play with girls'. Therefore, creating software geared towards boys seems okay since they are attracting both boys and girls. A circular logic exists because boys buy games geared towards boys and games are geared towards boys since boys buy games. Nickelodeon is a perfect example of taking a male-dominated form of entertainment and making it gender neutral so that young girls can take part. Before Nickelodeon, television was geared towards boys since girls would "watch anything." As soon as Nickelodeon started creating quality television for all children both boys and girls tuned in and ratings skyrocketed (Gillen, 1994).

Unfortunately, the problem is not as simple as creating games with female protagonists and textured backgrounds and music. Part of the problem stems from household interaction with computers. It is often the case that the men of the house actually choose and purchase the "family" computer as well as the accompanying software. The female members of the family never have a chance to input their desires. Since fathers and brothers tend to make the majority if not all of the software purchases for their family, marketers must package potentially female-friendly games as educational or adventuresome in order to appeal to the fathers and brothers respectively (Chaika, 2000).

An additional problem is how stores sell computing software. Often they divide the software titles into two main categories: software for fun and software for education. Upon viewing each of these categories it is painfully obvious that the software for fun titles target young boys while the educational packages target the female population. This only reinforces the typically female view that computers are tools and not devices used for fun. Boys on the other hand are bombarded with software titles promising a whopping good time. In fact, one software title targeted completely at young girls, *Barbie and Her Magical Dream House*, lists four different skills to be exercised while playing with the software. Even software titles available to young girls that should represent nothing but fun try to incorporate an educational twist. Why is it so awful to think that girls could actually sit down at a computer and have a little fun instead of trying to learn something new? Since girls tend to view computers as tools while men view them as toys it is very important to expose young girls to the entertaining aspects of computing (Bulkeley, 1994).

### ***Girls Preferences***

A study conducted in collaboration by Girl's Inc. (Austin, Texas) and the Center for Research on Parallel Computation at Rice University investigated girls' preferences in

software design. Ten girls from grades 6-12 were asked to examine and rate several different computing programs. The study revealed some interesting results. Game developers would do well to incorporate some of these results into their designs.

1. The girls refused to ever use a software manual when they had a question concerning the software they were working with. Instead, they would ask for help or look around for another available computer with different software.
2. None of the girls felt an overwhelming need to reach closure before continuing on to the next piece of software. Instead of attempting to complete a level of the game the girls enjoyed wandering around freely within the software environment.
3. The quality of the visual and audio presentations was very important to all the girls.
4. Most of the participants noted the need to have a challenging but not impossible task to complete.
5. The younger participants enjoyed the game-oriented software, whereas the older participants enjoyed the educationally focused software.

Further discussion with the female participants provided the following suggestions for potential software titles.

1. Many girls entertained the thought of virtual software in which they could experience bungee jumping, travel, shopping, as well as house and clothing design.
2. Software titles providing a way to experience possible career choices and lifestyles were suggested by the female participants.
3. Interactions with males also proved to be a popular suggestion. The ability to talk to other guys online was suggested.
4. The girls enjoyed the thought of being able to take part in a particular television show and even change the outcome of various online talk shows and sitcoms.
5. A majority of the girls were interested in other online environments, allowing students from various cultures to interact.

## **Mentoring and Role Models**

### ***Mentoring***

Mentoring programs have been shown to help the recruiting and retention rates of women in computer science (Sturm & Moroh, 1994). Mentoring is defined traditionally as a supportive relationship, sustained over a period of time, between a more experienced person (the mentor) and a less experienced person (the mentee). In most cases, traditional mentoring consists of face-to-face interactions where both participants are geographically co-located. Current mentoring programs are taking this traditional approach a step further by enhancing the mentoring process via the Internet and e-mail: this process is often called telementoring (Pathways, 2001; MentorNet, 1999; Bennett et

al. 1997; CCT 1996; Mather 1997; Bennett 1997). With this approach, the mentors and mentees communicate mainly through e-mail and electronic bulletin boards. The goal of these mentoring programs is to break down barriers of time and distance and provide support to the mentees.

Within the field of computer science, two key forms of female mentoring have arisen over time: mentoring for recruitment and mentoring for retention. Mentoring for recruitment usually targets female high school students. More often than not, these young girls have never been exposed to a true computing class or a CS female role model. Many young women begin their college experiences without the adequate computing skills and confidence needed to declare a computing major. Mentors and role models are therefore needed in today's high schools to encourage female students to enroll and excel in mathematics and computer science courses.

Mentoring for retention typically targets women who have already committed to the field of computer science. This form of mentoring can take place both in college settings with undergraduates, graduate students, faculty members or in industry. At one time or another, each woman needs support and encouragement to overcome the many obstacles women face in computer-related environments. Retention focused mentoring not only allows for peer-to-peer mentoring but it also creates a networked environment, which allows mentors in higher positions to pull their mentees up the ladder of success.

### ***Role Models***

One proven method to increase the numbers of women in computing is through role models. Women role models demonstrate the presence, the participation, and the continuing prospects of women in the CS fields. When young women think about computing as a career choice, the presence of successful women in CS is an encouraging signal. Not only do senior women scientists serve as role models in terms of scientific excellence; but young women also appreciate models of balancing a CS career with family and other aspects of life.

Girls and young women need women role models in CS related professions who can inspire interest in CS careers and who can demonstrate to them that computer scientists have whole and satisfying lives inside and outside the workplace (Brunner & Bennett, 1997). There can be many types of role models. Girls can interact with women computer scientists online or in person, where they serve as short term mentors. Pathways is an example of an online environment that facilitates real time chats with girls and scientists (Pathways, 2001). Expanding Your Horizons is a great example of face to face interaction (EYH, 2001), where girls attend an all day conference and participate in several small science-based workshops and interact directly with women scientists. Interaction with role models can break the isolation many women feel in the CS field, by enabling them to share their difficult experiences with women scientist who can validate their impressions and feelings. Role models can also guide students in dealing with conflicts and provide career advice and other expert knowledge.

Non-interactive role models can be seen or experienced from afar via biographies in text format or via public talks given by prominent women scientists (Townsend, 1996; Morrow & Perl, 1998; Perl, 1978, 1993). The bottom line is, girls and women need to

see other women that are successful computer scientists, where success is not only measured in technical expertise but also in their lifestyles.

Another form of role modeling comes from the history of computing. Here you can find a wealth of women role models (Gürer, 1998). Even though it is not well documented by the computing community, women made substantial contributions to the field of computer science (Gürer, 1995; 1996; Spertus & Gürer, 1998). Often times, these pioneers go unrecognized for their achievements, with the exception of Ada Lovelace and Grace Hopper. Even so, women were the first programmers: Lovelace was the first to conceptualize programming and the first six programmers of the world's first electronic computing machine (the ENIAC) were all women. Women have continued to break new paths in computer science. Through the efforts of ACM-W<sup>5</sup> and IWT<sup>6</sup>, achievements of pioneering CS women are being brought to light and can serve as excellent role models.

### ***Female Mentors***

Mentors can be found in all shapes, sizes, and genders. Male upperclassmen, graduate students, and faculty members can provide encouragement and support to female students. However, studies indicate that women and girls are best mentored by women (MentorNet, 1999; Pearl et. al., 1990). For example, a successful mentoring program (Walker & Rodger, 1996) matched female faculty with female graduate students, female graduate students with undergraduate female students considering graduate studies, and local female alumni with the female undergraduate students who were not planning to continue their academic careers. The goal of these mentoring relationships was to retain the women students as computer science majors. Establishing mentoring relationships in this way enabled women at each level to be in contact with women at higher levels. In addition, graduate and undergraduate students reaped the rewards of being mentors themselves (e.g., increased self-confidence and reinforcement of their own learning processes).

More advanced female students make good candidates for mentors. Not only do they provide younger female students with a role model to look up to but they also gain invaluable experience at the same time. As an example, placing female computer science students in a lab setting with positions of power ranging from a typical lab assistant to a more powerful systems administrator allows them to serve as mentors while gaining experience in a typical computing setting. This experience bolsters their self-confidence which in turn may prompt them to seek out other opportunities (Fossum & Haller, 1998).

All faculty members, including men, are capable of aiding a female student with her academic concerns. These concerns may range from raising a grade in a particular class to choosing an appropriate set of graduate schools. Men encounter many of these

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<sup>5</sup> ACM-W is sponsoring two documentaries on women in computing (the ENIAC Pioneers and Ada Lovelace) and has sponsored numerous papers and workshops on the history of women in computing (see <http://www.acm.org/women> for more details).

<sup>6</sup> The Institute for Women in Technology (IWT) sponsors the Grace Hopper Conference of Women in Computing which celebrates women's achievements in CS (see <http://www.iwt.org> for more details).

same obstacles and are therefore qualified to provide insight into possible solutions. In fact, men may be able to offer “specialized” advice when dealing with other male professors or staff. More than likely, male faculty are familiar with the workings of the “old boys network” and often have an insiders viewpoint on how to get around many deterrents that all students, including females, may encounter. However, men must also possess “an appropriate sensitivity to the problems that women in computer science may face” (Pearl et. al., 1990). Concerns with respect to balancing a career with family life, sexual harassment, gender discrimination, and the glass ceiling may be uncomfortable for both the male mentor and female mentee to discuss.

Although both students and male faculty members provide excellent sources for potential mentors, most people agree that female professors provide the most appropriate form of mentoring. It seems to make sense that a certain level of comfort may be achieved between a young female student and an accomplished female professor. Both the mentor and mentee are free to “let their guard down” (CRA-DMP, 1999) and speak freely of their concerns, aspirations, and fears.

### ***Mentoring Approaches***

Though female computer scientists make the ideal mentors, there is a lack of females in CS. Similarly, it is nearly impossible to provide enough mentors for every female student who either needs encouragement to participate in computer science or support in order to keep from leaving the field. Clever solutions must be implemented in order to stretch this limited resource as far as possible, such as summer research camps or telementoring.

Summer research projects are one way to promote and retain women in CS. This gives high school women the opportunity to take part in computer science research for the duration of two to three months. Participants are surrounded by other young women and female professors who are interested and excited by computing, and this in turn helps them gain a sense of confidence when using a computer. Such programs allow high school women to view computers as useful and even entertaining. As an example, the PipeLINK program targets female high school students, allowing them the opportunity to gain experience and confidence in using email, creating home pages, and programming in C++ (Walker & Rodger, 1996). Most male high school students have already gained skills in one or more of these areas so PipeLINK and other similar programs allow teenage girls the opportunity to catch up with their male counterparts.

Other similar programs have been established that target undergraduate women who are eligible to apply to graduate school or have already joined a graduate program in computer science. PipeLINK also targets these women by encouraging undergraduate women to participate in various research projects with a female mentor. It should be noted that PipeLINK boasts very successful results with this program. Not only does it expose high school females to computing but it has also convinced many of its participants to continue their education in a graduate program (Walker & Rodger, 1996).

A similar program endorsed by the Computing Research Association is called the Distributed Mentor Project (DMP). Here, undergraduate women are invited to engage in research for a summer. The majority of women who completed this project raved of its success. They enjoyed having a mentor that they could count on and knew that the

experience they had obtained would give them the confidence and experience to join a graduate program in CS (CRA-DMP, 1999). It has been suggested that programs such as these focus on those students from small colleges that lack research departments of their own. Women who have already been accepted into prestigious undergraduate programs have many doors open to them. Summer research programs will give them an opportunity to enhance the skills they have obtained in class as well as the ability to “beef up” their resume.

Unfortunately, due to budget constraints it is often difficult to implement such programs despite the overwhelming amount of success they report. However, many other clever and less expensive (in both time and money) solutions exist and should not be ignored. For example a program that used video-taped role models was highly successful (Townsend, 1996). The first video portrays two different subjects; a computer science major and an art major who had taken a single computing class. The computer science major spoke of her life both before and during college, her plans for the future, possible career options and the difficulties she encountered while starting a family during her junior year. The art major spoke of the incredible breakthrough she made in her department as a result of taking a single computing class. The knowledge she obtained in that one CS class allowed her to become the first senior in her department to incorporate a computer into her senior art project. The negative or indifferent attitudes that female high school students had towards computers changed drastically after viewing this videotape (Townsend, 1996). Advantages of using a video-taped approach are: the role models do not have to sacrifice a considerable amount of their time, it is less expensive in the long term, and the tapes can easily be compiled into a video collection.

### ***Good Mentors and Mentees***

Clearly not every professor, graduate student, or upperclassman will possess the qualities needed in order to be a good mentor and provide students with the guidance and advice they may need. A clear understanding of the role a mentor assumes must be understood from the start. In particular, a good mentor needs to set forth boundaries in relation to the type of help they provide their mentees. It is not the job of a mentor to take over a project or provide their mentee with too much information. Instead, an ideal mentor will address any questions their mentee may have with just enough information to clear up questions that exist. Providing more information may inhibit the student from drawing from their own knowledge and problem solving skills in order to obtain an appropriate solution. In addition a mentor should attempt to provide a friendly atmosphere for their mentees. They can accomplish this by initially taking a leadership role in setting dates for meetings and defining the context of these meetings. Often, young women feel inexperienced which leads to a reluctance to speak up and risk looking ignorant. Therefore, the mentor should take the initiative until their mentee feels comfortable. A mentor should also be sure that their interests match those of any potential mentees (CRA-DMP, 1999) and they should view themselves as critical to the process and success of their mentee. (Mertz & Pflieger, 1995).

Mentees must eventually become comfortable enough with their mentor to take a very active role in the relationship. A basic recommendation for mentees is to prepare for their mentor-mentee meetings. By preparing a list of topics to discuss, planning what they hope to get out of the meeting, summarizing the progress they have made since the

last meeting, creating a list of any upcoming deadlines, and reviewing notes from previous meetings, the mentee assists the mentor in determining the actions that need to be taken next. Keeping an accurate journal of progress and taking accurate notes on anything that is read will also enable the mentee to keep themselves on track and help them set reasonable goals. Finally, students should make an effort to talk about their research with outside sources to help them gain an overall perspective of their project (Pratt, 1999).

Even though it is likely that no two people will be completely compatible as a mentor-mentee pair there are several steps that can be taken to promote a successful relationship. Although a mentor-mentee pair must experiment at first to determine actions that will benefit both participants, simple suggestions such as regularly scheduled meetings may ease this transition. It may also be helpful to have a supervisor for the pair. Although they would not be an overwhelming participant, having a supervisor with an unbiased viewpoint will introduce structure into the mentor-mentee relationship which may otherwise erode as more and more time is devoted to other projects by both participants. It also makes sense to carefully match advisors and advisees to ensure compatibility of interests as well as personality.

### **Self-Confidence**

A lack of self-confidence is one driving force that causes many women to leave or to not even enter the field of CS. Studies have shown that self-confidence hinges on four different components: performance and accomplishments, observing and learning from others, freedom from anxiety concerning work and conduct in a particular field, and persuasion and support from others (Ambrose et al., 1998). Many women fail to take credit for their accomplishments and superior performance, feel inadequate when observing or learning from others who appear to know so much more, experience extreme amounts of anxiety, and do not obtain support from others in the field. In most cases, men do not suffer from this problem. In fact, they often go to the other extreme and have more confidence than is warranted. In this type of environment, women cannot be expected to thrive as men do.

A lack of self-confidence starts early in the pipeline. A study of seventh grade students from Los Angeles, California found that girls experienced higher levels of discouragement and lower levels of self-confidence than their male counterparts. Strangely, the female students who were interviewed obtained marks very similar and even better than those achieved by the male students (Alper, 1993). It is discouraging to find that the majority of young girls are capable of performing just as well, if not better, than the young boys, and yet they have lower levels of self-esteem. The girls were constantly underestimating their abilities which in turn kept many from continuing their education in math and science. Obviously, this will restrict their involvement in technical careers such as CS later in life. Thus the pipeline starts to shrink even at this early age.

The majority of females majoring in computer science admit that their self-confidence begins declining as early as their first year and continues to decline every year they are in college. Females tend to enter computer science programs with a certain level of fascination and excitement and leave the same computer science program (either prematurely or with a diploma) without a sense of competency and an extremely low level of self-esteem (Pearl et al., 1990). Researchers at UCLA found that women who

attend very small, prestigious colleges commonly experience the largest decline in self-esteem and the highest attrition rates due to the extreme amount of competition found in such environments (Alper, 1993). This intense competition only decreases already low levels of self-esteem in women.

Reasons for such blatant decreases in self-confidence can, in part, be traced back to the actions of most professors. Female and male professors both tend to remember the names of men better, call on them more, ask them more challenging questions, and interact with male students more than females (Levenson, 1999). The actions by the professors is usually not deliberate, however, such forms of favoritism create an uncomfortable environment by themselves. The problem is exacerbated even more when a professor's favoritism is combined with sexism from male students. Many women are uncomfortable in asking questions in class and seek extra help outside of class time for fear that other students will view them as being ignorant. Many male students tend to haze women when they are not familiar with a certain computerized concepts by insinuating that such basic ideas should be well known to all computer science majors. Statements such as, "You're a computer science major and don't know that?" send a woman's self-esteem plunging through the floor (Fisher et al., 1999).

However, it is important to remember that students who lack confidence in their computing abilities were at one time excited about the field of CS. This seems to indicate that they had once had a certain high level of confidence (Ambrose et al., 1998). Women who enroll in CS programs understand the hardships and struggles associated with studying technical subjects. When they meet with discrimination and harassment, they start to lose the confidence they once had. Once this cycle starts, it is hard to reverse and they lose faith in themselves and their abilities. It is important to understand that it is the loss of self-confidence and not technical difficulty that leads women to drop out of CS.

### ***Perceived Competence***

Women also tend to believe that they lack the same knowledge that "everyone else" has already acquired. By the end of their college careers, most women have actually caught up to their male classmates (Fisher et al., 1997) in terms of computer knowledge but still refuse to give themselves credit for such an admirable accomplishment. Instead, women remain convinced that the "I know more about computers than you do" hierarchy still exists, with the men understanding more than the women (Fisher et al., 1999). The subsequent alienation that many female computer science students face inhibits them from seeing and accepting the fact that they often outscore the men in many computer related exams. For example, at the College of Staten Island (City University of New York) an exam covering introductory computer science, assembler programming, pre-calculus and advanced calculus was distributed. Although both the women and men taking the exam agreed beforehand that men usually performed better in such areas, the women actually obtained the highest scores and outscored the men (Moroh & Sturm, 1995).

Why do women tend to harshly blame themselves when they do not perform perfectly and refuse to take credit for their actions when they are successful? As one female student said, "It is much worse if a woman fails an exam because her self-confidence is so low. I got an A minus on an exam and was upset. The man sitting next



to me got a C and he said, 'So what?'" (Etzkowitz et. al., 1999) Such low-levels of self-esteem are rarely seen in male computer scientists. In a study of valedictorians from Illinois it was found that right after graduating from high school 20% of all the students (both male and female) viewed themselves as being more intelligent than their fellow peers. By the end of college, 25% of the men still viewed themselves as being more intelligent than their peers but not a single woman placed herself in such a prestigious category, despite the fact that the women overall had a slightly higher grade point average than the men (3.6 vs. 3.5) (Levenson, 1999). Similarly, a Stanford study found that women believed themselves to be less than prepared for graduate school despite objective data showing that their academic backgrounds were comparable to their male peers (Levenson, 1999).

## **Computing Environments**

In order for our society to see large changes in the number of women who opt for a career in computing the typical computing environment is going to have to change drastically. At very young ages schoolgirls become familiar with male-dominated computer labs. Those women who enroll in a collegiate computer program often encounter demeaning remarks such as "You only got into this school because you are a girl." Professional female computer scientists often feel out of place in their work environment since they are unable to "bond" with their male counterparts due to differing interests. At every step along the way, females encounter situations that make them uncomfortable, thereby making the computing world a hostile place for women.

## ***Male-Dominated Environments***

At first glance, computing seems to be a very attractive career choice for women (Newton, 1991). In today's high-tech society computing careers offer independence and security along with a clean, modern environment. The pay is good and the problems are challenging, often requiring a team effort. The hours are often flexible and working from home is an attractive option where all that is needed is a high end personal computer and an Internet connection. These last two attributes are especially important for working mothers.

However, men tend to encourage the creation of uncomfortable and even hostile environments for women, in many cases unknowingly. For instance, many men consider manual dexterity and a thorough understanding of all computing tools mandatory for all "true" computer scientists. Young girls and even professional female computer scientists do not feel compelled to tinker around with old parts and memorize the name of every computing tool in existence (Wright, 1996). This puts them at an obvious disadvantage despite the fact that being a successful computer scientist does not require such skills.

Interestingly, computer science started out as a women friendly place. CS or programming was seen as a job women were good at (Gürer, 1995). It was not until computing gained more prestige that the male bureaucracy moved in and the computing environment became almost exclusively male. Females at all levels of computing quickly became familiar with fighting off males who attempted to take over their projects (Kantrowitz, 1994). Unfortunately, many young girls do not feel comfortable fighting off their male colleagues. This discomfort is only aggravated, since males tend to show off, take over the computer lab, profess their unwavering knowledge of computers, and make

fun of others when they make mistakes. In higher levels of computing the situation worsens when men tell jokes comparing women to computers and display pictures of naked women in their offices or on their computer screens. Although this may be considered typical behavior from many men and is not meant to turn women away, most females tend to feel uncomfortable when forced into these environments (Spertus, 1999).

Computer labs prove to be another computing realm that is off limits to girls. Females, in general, tend to enjoy attractive rooms and computer labs are usually just the opposite. Males are commonly indifferent as to whether or not the computing lab is welcoming or aesthetically pleasing. Furthermore, most lab assistants are male and may have the tendency to make others feel inadequate as they flash their expertise in ways that make others feel stupid and uncomfortable (McCormick & McCormick, 1991). They use computers to exert their masculinity (Huang et al., 1999) and when asked how to complete a certain computing task, tend to take over as they begin fiddling around, moving files, adding files, modifying settings, all the while never explaining to the novice why such actions are needed (Kiesler et al., 1986). At this point, many females start questioning their own abilities as computer scientists.

### ***Working Mothers***

Working moms have a particularly difficult time in today's work environments. Whether we care to admit it or not, the majority of the childcare in a family is still placed on the woman. This is especially true in the first few years of a child's life when the mother is likely to be breastfeeding. Most managers do not understand the necessity of nursing and do not support it. Companies need clean private rooms where women can pump during the day. This is crucial since if one stops pumping, the milk supply dries up. Managers need to understand that their employee may need to take some time during the day to express milk and should encourage it. In many cases women are forced to pump in dirty bathrooms or in non-private rooms. In addition, they are often the subject of jokes such as cow or "moo" jokes (Brady, 2001).

In addition to flexibility for nursing moms, companies need assist with childcare. In today's workplace, many employees commute long distances and it is difficult to find convenient good quality childcare. Companies should make every effort to provide on-site daycare or support a center close by. Flexible hours and telecommuting should also be encouraged and supported. Many moms can be 100 percent productive, but need to be able to have the flexibility to care for their children as needed (e.g., doctors visits, sick childcare, and so on).

### ***Using Language to Push Women Out***

Men also tend to use offensive and harsh forms of language in order to convey their ideas. Metaphors have become very important to the field of computer science in order to relate different concepts and how they fit into our world. In typical computing conversation it is common to hear war metaphors such as "leading the squadron", "meeting in the bunker", "we're taking no prisoners", "the bleeding edge", along with sexual metaphors such as the "hard end" of production or avoiding "cock-ups" (Wilson, 1992). Although it is probably safe to assume that none of these metaphors were purposely used to offend women, they do create an uncomfortable environment. Even

online men use language to keep women away. Men in the computing world can be very harsh. Women often encounter and are offended by the “Listen, baby, if you don’t like it, drop dead” attitude that men commonly use with each other (Kantrowitz, 1994). As a final example, a group of men named a system they created F.A.L.L.U.S. and actually advertised it as “a firm favorite, an uprising, pulsating tower of strength that shows breath-taking expandability and has a tempting range of speeds that will more than satisfy your needs” (Mahony & Van Toen, 1990).

### ***Lack of Female Companionship***

Many women in computing also find it difficult to bond with the males they are working with. Talk of cars and sports may not provide women with the opportunity to join in everyday conversation. Joining men in after-hours social gatherings is also difficult since men (for example) tend to shoot hoops, golf, and go out drinking. It is commonplace for men to make lewd comments after a couple drinks and many women may not feel comfortable battling it out with the guys on the basketball court or golf course (Spertus, 1999). This only compounds the alienation women feel at the office and it excludes women from important work-related relationships and discussions. Although not a cure-all, employing a critical mass of women into computing departments will help alleviate some of this discomfort (Etzkowitz et al., 1999). Also, allowing women to advance beyond middle management positions (Kantrowitz, 1994) will not only create a more welcoming environment for women in lower positions but it will also provide young girls with role models to look up to.

Many women also experience a sense of severe isolation and pressure in a classroom setting. When there are only one or two women in an entire computing course they tend to stick out. Everyone in the classroom remembers anything they say, or do not say. Although these women are extremely hesitant to speak up for fear of being wrong and giving the female gender a bad name, many of them feel as though they must speak up in order to prove to their classmates and professors that women are competent too. Many women also feel they are put into the situation where they need to prove themselves. Their male counterparts are assumed to have the knowledge they need, however, women are assumed not to have the knowledge. Thus women have to work to gain respect, while men have to work at losing respect. Thus, women are at a disadvantage and feel as though they must complete exceptional work in order to be taken seriously (CRA-DMP, 1999).

### ***Educational Complications***

As mentioned above, many female students enrolled in computer science courses feel isolated and are forced to complete the course on their own without the study groups that many male students form. The problem is only worsened when educators assign problems that are from male domains. For example, programming assignments designed to compute football statistics may be harmful for girls. Those few girls who enrolled in the computing class will be ridiculed for not knowing the names of football teams or confusing them with teams from other sports (Huang et al., 1999). This only makes the female students feel more isolated and more likely to leave the computing field.

Gender neutral or open-ended assignments should be presented in order to alleviate such biases. Easily avoidable instances of a male-oriented environment only compound the alien culture girls find themselves in. This is in addition to mischievous acts such as faking accounts, stealing computing time, breaking codes, and copying software that are commonly encouraged and admired by other boy/hackers. In addition, contests to see who creates the best, fastest, biggest program discourage girls (Kiesler, 1986). Females are often more interested in producing something useful, rather than something bigger or faster.

It is also important to consider the atmosphere presented at computing club meetings. Women need to be prominent figures in these clubs in order to encourage other interested females to join. Since few women in computing exist, it becomes very important to recruit women from other departments and specialties. Once an adequate number of women join the club it is imperative to consider the activities the club participates in. Doom tournaments and programming contests are great for the male gender, however, activities involving person-to-person interaction and socialization will entice females. As an example, a special interest musical group may enjoy presenting their work on computer-generated music (Carlstead, 1999).

### **Family and Teacher Encouragement**

Despite the fact that most female computer scientists love computers and would never consider another line of work, a large percentage of these same women admit that they never thought of working with computers as a career until an outside source suggested they do so. Both family and teacher/counselor encouragement have been cited as two of the most influential sources of inspiration for women majoring in computer science. Both types of encouragement have proven effective at all educational levels, however, the earlier an authority figure is able to point out the opportunities available to women in computer science the better. It is to the dismay of many that teachers, counselors, and even parental figures often perpetuate typical stereotypes suggesting that computing is a male domain. This section will examine each source of encouragement separately.

#### ***Teacher and Counselor Encouragement***

Both teachers and counselors alike are responsible for guiding students into academic areas that they excel in. Without regard to sex, it makes sense to suggest programs where students exhibit talent, whether it is for liberal arts, science, or computer science. Unfortunately, in past years, teachers placed an emphasis on persuading girls to strengthen their writing skills while boys were encouraged to work through formulas and equations.

In today's classrooms, many teachers attempt to combat such harmful practices by providing gender-neutral atmospheres in the math and science classrooms. This is thought to ensure an enjoyable experience for all students, however, the problem is most girls have been conditioned to believe that math and science are still male domains and avoid enrolling in such classes. Therefore, teachers need to take direct measures to encourage female students to enroll in math and science, and computer science classes (Culley, 1988). It is crucial teachers become involved since schools are a key factor in

the creation of stereotypic gender roles. Rather than perpetuating the negative images of girls and computer science, schools can help reverse these mindsets.

Typically, classrooms that do not provide a gender-neutral atmosphere promote a male-oriented domain. With a few exceptions, instruction for computing courses is provided by male math teachers (Culley, 1988). This automatically starts the process of creating a male-dominated environment that female enrollees have to overcome. Furthermore, it has been observed that computer science instructors of both sexes devote more time to their male students. This is due to the male students being more noticeable by raising their hands in class more frequently, being more vocal, and so on. Unfortunately, this causes the teachers to ignore the needs of their female pupils. Huber and Scaglione observed a mandatory computer course taught in a Costa Rican school (Huber & Scaglione, 1995) where both a computer lab instructor and the regular classroom teacher were present for the entire duration of the computing course. The authors noted that 60% of the lab instructor's time and 54% of the classroom teacher's time was devoted to male students. Not only did the female students receive less instruction than their male classmates, but the attention they did receive came from the regular classroom teacher who was not as skilled in computers as the lab instructor. This is a typical example of educators allowing male students to gain the upper hand in the classrooms and obtain technical skills while female students do not.

### ***Family Encouragement***

Even though parents strive to provide their child with a safe and nurturing environment in which to develop into an adult, many parents unknowingly raise their children in gender-biased households. In today's society, it is the ambition of most parents to raise technically aware children so that they may have the opportunity to take advantage of today's most successful, technically oriented careers. Unfortunately, many parents provide obstacles for their own daughters and through subtle biases provide more support for their male children.

One problem is the majority of "family" computers are typically set up in the son's bedroom (Brzowsky, 1999). Not only does this create a feeling of bias towards the son, but it also makes it much more difficult for the young daughter to obtain her own computing time. Ideally, computers should be set up in a family area where everyone has equal access.

Mothers also play a very important role in their daughter's perception of technology. If a technically challenged mother presents herself with a fearless attitude when manipulating computers and other technical devices, her daughter will mimic that same attitude. Suggestions for increasing both a mother's and daughter's knowledge of computers include taking a junked computer apart or backing up all settings on the family computer to allow mother and daughter to try out everything the computer offers. By first backing up the system, both participants will feel comfortable in taking the same risks boys do, because they are assured of not being able to break the machine (Adelson, 1999). The ability to interact with their mother interested in expanding her own technical knowledge will provide young girls with the state of mind and skills needed to succeed in other areas of computer science (Huang et al., 1999).

Finally, it goes without saying that children need a great deal of love and security in order to grow up with positive self-esteem. Girls have been lacking self-esteem for generations and without self-confidence it is almost impossible to break new ground and experience new things (Graves, 1999). Therefore, it seems imperative that parents and teachers alike take every opportunity available to recognize young girls for their accomplishments and encourage them to take risks and accept challenges.

### **All-Female Environment**

During the early years of middle school young female students often find themselves in a confusing situation. Society, family, friends, and teachers have perpetuated the idea that subjects such as mathematics, science, and computing are not appropriate for girls, even though many girls may have excelled in such classes during their elementary school years. Consequently, many bright female students who obtained the highest marks in their elementary school classes suddenly begin to perform at lower levels than would be expected. This trend, unfortunately, continues in higher levels of education. A study conducted at UCLA found that those women who attend very small, co-ed prestigious schools tend to have the largest decline in self-confidence and the highest dropout rate of any other group of women choosing similar majors. Male students tend to enjoy the extreme amounts of competition found at these institutions. In stark contrast, this intense competition does nothing but decrease a typical female's already low self-esteem (Alper, 1993).

In other related studies it has often been noted that those women who attend all-female institutions graduate with greater self-confidence and tend to experience higher levels of career success (Corston & Coleman, 1996). One effect of all-female institutions is that female students no longer have to contend with the "I am not smart enough." intimidation that can usually be traced back to the perception that males are better in subjects such as math and science. Furthermore, male students tend to dominate and lead classroom discussions where they tend to speak up faster and louder than the female students. Most people would agree that the person who attempts to answer the most questions is not necessarily the most intelligent in the classroom (Frank-Loron et al, 1999). Having an all-female classroom allows women's voices to be heard and many women to overcome their reluctance to speak out.

### **All-Female Environments**

Many areas of education exist which provide ideal situations to implement all-female environments. These can take the form of a small all-female club, a slightly larger all-female class, and even an all-female school or university.

All-female clubs can be found in high schools, universities, and in industry. They offer a special environment that a classroom or the workplace cannot provide. Membership in a club offers a special feeling of belonging and the knowledge that what the club stands for is important. This relaxed environment may facilitate discussions and a chance for mentoring relationships to form since students or personnel from many levels will usually join. An all-female computer club at a high school, for example, adds an element of socialization to the intellectual study of computers, an aspect welcomed by females of all ages.

The intimidation of math and science felt by the majority of young female students may be greatly diminished by creating an isolated environment for girls (Frank-Loron et al, 1999). Female participants will no longer feel as though they must battle the boys to state an opinion or ask a question. As an example, a mother named Maureen Castellana started an all-female science club in order to ensure her daughter would not fall victim to basic societal downfalls and lose interest in science. The girls who joined Maureen's club entered a robot-building contest at MIT and stole the hearts of the audience when they beat a team from Microsoft. It was concluded that the girls' success could be partially attributed to the fact that they were willing to take risks and make mistakes. This would likely not have happened if there were boys in the group (Travis, 1993).

On a slightly larger scale, all-female classes in K-12 schools and universities also provide an appropriate outlet for females interested in math and science. A female student enrolled in an all-female, middle school, computing course was quoted as saying, "I felt more free to say stuff even if I wasn't sure it was correct. I felt more comfortable in math and science and asking questions. I also shared more and demonstrated." Although many opponents to gender split classes have stated that it is harmful to portray female students as special and in need of extra help, proponents of such environments believe that when girls are comfortable in class they will be able to focus on their studies without unneeded distractions (Murray, 1995). In addition, female instructors seem to increase performance significantly in all-female classrooms (Corston & Coleman, 1996).

All-female schools and universities may also provide environments that promote success for female students in math and science. Kathleen Bennett founded a successful all-girl middle school to avoid the "wall of femininity" that girls in grades 7-9 so often encounter. The all-female environment welcomes the girls and allows them to forget the coed pressures that often distract them from their studies. Furthermore, project-based learning, friendly computer labs, and group projects have been implemented which encourage the girls to use and learn about computers without having to first fight off the boys (Huang et al, 1999).

It should also be noted that young boys also tend to benefit from gender split classes since they also confront coed pressures while attending class. When separating the boys from the girls, the boys are often quieter than in the past and seem to work more cooperatively than before. The boys themselves even admit that their classroom environment is more welcoming and less competitive since they no longer "need to show off to the girls" (Murray, 1995).

## **Equal Access**

Equal access to computers is crucial to increasing the numbers of women in the CS pipeline. Adequate amounts of individual computing time will ensure they obtain the computing skills needed in the future (Hearne & Martin, 1989). However, many school districts lack the funds needed to provide their students with enough computers to allow each student their own personal time on a machine. Instead, students must work in partners which often becomes a detrimental situation for females. Males tend to be extremely skilled at monopolizing the computer even though it appears to their teachers that they are sharing the computing time fairly. Even as very young children males begin to seek control over computing labs and access to computing time.

Teachers commonly delegate computing time as a reward for completion of homework assignments. One such teacher noticed that the girls in his classroom never played on the computer. Instead, they would help their friends finish up homework assignments or refuse to use the computer because they viewed computing as the boys' activity. Another math teacher, who similarly rewarded her students with computing time, became discouraged when she realized that she had never seen her young girls play with the class computer. They were usually too busy concentrating on the details and neatness of their assignment to worry about the computer. As a solution, many teachers grant female students time on the class computer by forcing the young boys to move on to another subject. However, forcibly removing the boys from computing environments in order to allow the girls to take over is also harmful. Girls must learn how to independently become competitive with their male classmates at an early age (Huang et al., 1999).

### ***Female vs. Male Performance***

In a computing environment, boys tend to take on the role of hosts whereas females act as guests (Elkjaer, 1992). Hosts are defined as those people who are part of a particular discipline and feel as though they must completely understand the associated material. Guests are people who are simply interested in a particular discipline, have a basic understanding of the associated concepts, and are comfortable in making mistakes in order to increase their knowledge and familiarity with the discipline. Thus, boys tend to take over in an attempt to prove their knowledge while the girls feel comfortable in sitting back, watching the boys, and admitting that they are less knowledgeable than their male counterparts. Girls are voluntarily giving up their computing time and unknowingly allowing the boys to gain more experience.

It is encouraging to note that given the opportunity to gain computing experience, girls are capable of evenly competing with boys. At the College of Staten Island (City University of New York), a study found that although both sexes felt as though men performed at a higher computing level than women, the participating females actually outperformed the men in introductory computer classes, assembler programming, pre-calculus and advanced calculus (Moroh & Sturm, 1995). Similarly, women scored significantly higher than men on every question in the Problem Analysis portion of the Minnesota Computer Literacy Assessment (Anderson, 1987), where the questions demanded a clear understanding of the problem itself as well as the ability to design and outline solutions for it. According to the literacy assessment, the results indicate that women are prime candidates for positions in informatics which is defined as the science of information, its organization, and manipulation. Thus it is vital that girls gain as much computing experience as they can during their early school years.

### **Graduate School**

The pipeline for women in CS drops off dramatically for women continuing on to graduate school. Encouraging female undergraduate students to apply to a computer science program at the graduate level is very difficult. First, the majority of prospective, female candidates are lost before they obtain an undergraduate degree, thus making it difficult to seek out qualified individuals. Second, those who are qualified are usually tired of coping with the typical non-women-friendly computer science environment and



vehemently decline the offer. In addition, those few qualified women who consider continuing their education rarely understand how graduate school environments differ from the undergraduate lifestyle they are familiar with and may drop out in their first year of study (CRA-DMP, 1999).

In order to interest female CS majors in graduate school, programs need to become available expose an undergraduate student to the exciting world of graduate studies. For example, the Distributed Mentor Project (DMP) was created in order to allow undergraduate women the opportunity to test their research skills in a graduate level environment (CRA-DMP, 1999). This successful summer program allows its female participants the chance to befriend faculty as well as graduate students as they experience a graduate student lifestyle. Programs such as DMP not only allow women the chance to decide whether or not they would like to join a graduate program, but it also eases the transition between the two educational levels for those who choose to extend their education. Providing women with this type of foundation and a clear understanding of the expectations involved in graduate work, not only may pique their interest in CS graduate work but may also increase the likelihood of success once they begin their own graduate program.

Other existing introductory programs focus on encouraging their female participants to search for solutions independently, rather than relying on their advisor or other students. As young girls, females are socialized to seek help and provide help to others rather than being self-reliant and competitive. Girls are encouraged to be good students by accepting a task, completing it well, and then receiving a reward from an authority figure. In stark contrast, behavior in graduate school is expected to be strategic, independent and void of interpersonal support (Eskowitz et al., 1999). Females are often criticized for seeking assistance at advanced levels of education, which further discourages them.

Even with programs such as these, many women fail to see all of the underlying “secrets” of graduate school and wind up joining a program with their eyes only half open, where their male counterparts do not. It is at this point that the department must work to provide an environment that will enable female students to experience both comfort and success. Departments must commit completely to retaining their female students. This means providing a female-friendly environment with the encouragement, mentoring, and support that the students need.

Being a graduate student is a difficult position. You are expected to perform independently and proactively on your research, while at the same time you are expected to still be a student and “listen” to your advisor. Graduate students are not paid much money and yet must take on all the responsibilities of life, many of which they were sheltered from as undergraduates. This is particularly difficult for those who are parents and are expecting or have small children. The department should take special efforts to ensure that the work environment for the graduate students is clean and safe and should also support parenting through flexible hours, home offices, and/or on-site daycare.

## **Balancing Work and Family**

Pregnancy and raising children still have negative impacts on women’s careers in the United States. It is especially difficult for those with infants and toddlers due to the

demands of both their offspring and work. Industry still has a way to go to provide appropriate environments that allow a new mother to also be productive at her job (e.g., on-site daycare, expressing private rooms, flexible hours, and so on). Some companies offer support and others do not. However, the situation seems to worsen in academia because of its inherent structural features. Academia requires almost exclusive attention to research achievement during the same years that many women contemplate starting a family (Eskowitz et al., 1999). Both graduate students working towards a degree and faculty members applying for tenure find it difficult to juggle both work and family. This impacts women far more than men.

In the past, the model for an academic career formed around the concept of a “helpmate-in-the-background” (Pearl et al., 1990) in those years when only men held academic positions. They were able to complete the work necessary to advance academically while their wives provided the background support needed to raise and support a family. It is still assumed today that men can accommodate a personal life (wife, kids etc.) because they do not have to take on responsibilities at home. However, times are changing. The majority of women work in the U.S. and men are taking on more of a role in the household. Even so, women still bear a larger share of the household chores.

Because many faculty members still view the traditional roles for women, women find it difficult to simply announce their engagement or their pregnancy. Professors and other administrators often insinuate that engaged females commonly devote too much time to planning their wedding and not enough time to their studies. The situation only worsens when a female graduate student or faculty member decides to have a baby. Since schools are often ill equipped to deal with pregnancy, temporary leaves of absence are commonly encouraged to become permanent (Eskowitz et al., 1999).

Even when women focus completely on their career and opt not to have children, they are often treated as though their commitment is not strong enough. Many women speak of unacceptable interviewing situations in which the interviewers continually suggest that the female interviewee will eventually put a family above her career aspirations (Hassoun & Soha, 1999). This kind of treatment is illegal but it still occurs. A study produced by the Army reports statistics showing that “even when pregnancy leave is included, [enlisted women] take less time off than men, who lose it to sports and auto injuries and drug, alcohol and discipline problems” (Spertus, 1999). It seems quite clear from this study alone that women are capable of handling both a family and a career if they so desire.

## **Societal Influence**

Few people will argue that although our society is making progress toward becoming a culture in which women are afforded the same opportunities as men, the progress is slow. Gender biases in relation to technology and technically oriented careers still permeate family life, our educational system, and the media. Due to this lack of support, and a resulting lack of experience in high school, summer jobs, internships, and computer camps, females are behind in computing skills when they reach college (Markoff, 1989).

## ***Family Life and Education***

Two areas where young students spend almost all of their time include family life and school. These are two areas where one would hope that gender biases have ceased to exist. Unfortunately, just the opposite is true. In today's educational system teachers still make more eye contact, devote more attention, and call more frequently upon the boys than the girls. Boys are even treated differently when they give an incorrect response. Teachers tend to encourage boys in their classrooms to find the correct answer by guiding them through the thought process required to obtain the correct answer. Girls, on the other hand, are given sympathy before the question is turned over to another male classmate. The discrimination continues in lab situations. The majority of lab experiments are actually conducted by male students so the females can record the results (Alper, 1993). The situation is only compounded when girls reach junior high and find it uncool to be smart (Markoff, 1989). They begin to graciously back down to the boys so as not to appear interested in the experiments or technology.

Families, including parental figures, contribute significantly to the computing interest their daughters develop (positive or negative). Many parents tend to encourage only their sons to attend computer camps and are willing to spend more money to send their sons to these camps than their own daughters. Parents also tend to place the "family" computer in the bedroom of the male child instead of in a family room, den, study, or another neutral room (Markoff, 1989).

Social environments make huge impacts on children and parents teach our children how to act like a boy or a girl, even though the physical development of all children is about the same until adolescence. It is at the point of adolescence that peer pressure is at its highest and many talented young girls lose all interest in science and technology, especially computers. Parents need to assure their daughters that they can be "girly" and still succeed in technological fields by introducing them to all forms of technology, including computers (Miller & Swanson, 1998).

## ***Media***

Media plays another important role in how girls perceive computer science. Inaccurate reports from various media sources proclaiming that women cannot compete with men genetically when it comes to math, science, and other technical fields, serve only to influence girls to avoid these crucial subjects. Furthermore, they reinforce archaic ideas that boys should be granted access to computers, both at home and at school, before girls because they need to prepare for their engineering careers (Klawe & Levenson, 1995).

Magazines also serve to reinforce these discriminatory ideas. Most computing magazines portray only men and young boys as being avid computer users (McCormick & McCormick, 1991). A study conducted by Struck and Ware (1985) found that out of a total of 426 illustrations found in 9 different magazines only 224 or 30.8% were of women and girls. Of those 224 illustrations, women were underrepresented as "managers, experts, and repair technicians" and were overly represented as "sellers, clerical workers, and sex objects." In contrast, men were commonly described as managers, sellers, experts, and repair technicians. Also, young boys were shown as game players in 20% of the illustrations while not a single picture of a girl playing video games

could be found. Finally, it should be noted that 362 out of 727 individuals were shown in settings in which hands-on use of the computers was required: 82.8% of the males in were actively using the computer, compared to 55.7% of the women. Finally, only women were ever depicted as rejecting a computer in these illustrations.

## **Other Forms of Discrimination**

Three important forms of discrimination fail to fall within the categories set forth in this document: subtle but constant discrimination, the invisibility syndrome, and hiring to keep women down. They are briefly discussed below.

### ***Subtle but Constant***

Many times men and women alike discriminate against female computer scientists in subtle ways that the perpetrators themselves may not even recognize (Pearl et al., 1990). It should be noted that despite the discrimination being subtle and/or unintentional, encountering such acts on a constant basis may be more harmful than a few overt incidents of discrimination. Subtle discrimination is rarely recognized simply because each individual act seems trivial. However, these “trivial” acts add up to a feeling of constant harassment. It’s been compared to the torture of a thousand cuts, where a single cut does not do much damage but the accumulated thousand cuts, can do great harm. What makes it more difficult is women feel they cannot complain about these subtle forms of discrimination because they will be seen as overly sensitive or as not being a team player.

### ***Invisibility Syndrome***

Even though many women hold respectable positions and produce outstanding results they are often overlooked when invitations to computer related functions and nominations for computer related awards are made (Pearl et al., 1990). Often what happens is a small group is in charge of nominating candidates for positions and this small group is all males. Understandably they tend to think of their friends and colleagues who are also male. A special effort need to be made to include women and minorities in all manner of professional groups. Nationwide organizations and corporations as well as individual departments must take measures to avoid such discrimination.

### ***Hiring to Keep Women Down***

An interesting finding by Ranson and Reeves revealed strange hiring practices of some prestigious companies. These corporations with a relatively high percentage of female employees (greater than 35%) would often hire women with skills inferior to their male counterparts (Gillian & Reeves, 1996). This allows the company to boast a high percentage of female employees but at the same time reserves positions of authority for their skilled male employees. Similarly, corporations that hire skilled women tend to have a lower percentage of female employees (less than 35%). Unfortunately, although these women are talented and capable of holding respectable positions, their lack of numbers keeps them from attaining the high paying jobs that are awarded to the men. In both situations women are kept from advancing due to either their lack of numbers or their lack of skill.

## Recommendations

In conclusion we provide a list of recommendations to attract and retain women in CS. These suggestions are culled from the numerous articles summarized, from other documented sources, and from ACM-W members own personal and researched experience in these matters.

### Attitudes

Recommendations for attitudes focus on providing girls and women with positive computing experiences. The hope is that when more women have positive computing experiences, more will chose to pursue computing as a major in college or as a career.

- **Equal Participation** – Ensure that instructors are educated to gender differences so they can facilitate computer labs where girls and boys have equal time and exposure to computers.
- **Equal Access** – Support programs that publicly provide computers to all students so those without computers at home will have the opportunity for exposure to computing.
- **Same Sex Instructors** – Expose female students to female computer scientists – whether they are instructors or visitors of the class. When possible, female instructors should be sought for computer science courses.

### Computer Experience

Recommendations for computer experience focus on providing the appropriate computer experience so women can succeed in college level computing courses.

- **Computing Programs for Girls** – Provide girls with early experiences with computing that will enable them to learn computer basics, computer jargon, and help them feel comfortable around computers. This could be in the form of special programs or scholarships to computer camps, workshops that focus on computing and made available to female students, online workshops to teach computing to girls, or organized visits to on the job women computer scientists.
- **Entry Level Collegiate Courses** – Initiate a course for those students who need to “catch up” on assumed prerequisites for a university’s entry level computer science classes (for both CS and non-CS majors).
- **Awareness of Disparity** – Educate CS faculty to the possibility of some of their students not having the assumed prerequisite computing experience. Encourage faculty to ascertain at the beginning of their classes the computing expertise of their students in a non-threatening way, and take action to bring those who need it, up to speed, or have professors assume no prior computing experience.
- **Consistent Labs** – Provide consistent computer labs that do not require students to constantly re-learn the system.
- **Consistent Assignments** – Encourage instructors to grade projects based only on the computing skills they explicitly assigned. In other words, do not allow those students who have more knowledge to obtain extra points by adding neat colors or other trivial bells and whistles to their programs.

- **Real-Life Experience** – College departments should allow female students the opportunity to apply their classroom knowledge to real-life problems in the form of research projects, internships, and so forth. This will allow female students to understand how their classroom experience can be applied in the real world and may encourage them to pursue CS as a career.

## Early in the Pipeline

Recommendations for early in the pipeline focus on approaches to increasing the numbers of women early in the pipeline from preschool to high school.

- **Discuss Gender Differences** – Train young students that gender differences in computing do not have to exist. This could occur via discussions led by the instructor about computers, whether computers are for boys and/or girls, and so on.
- **Educate Instructors** – Train instructors to understand gender differences and how to act on them. For example, allocating equal time on the computer for girls, calling on girls equally in the classroom, assigning difficult problems to girls as well as boys, allocating their time equally between girls and boys, and initiate interaction between them and their female students (Huber and Scaglione, 1995).
- **Educate Parents** – Create parent workshops to educate parents on today's inadequate computing practices that favor their sons. Show them how they can influence their daughters to have a positive experience with computers. Educate them on gender friendly software and encourage them to provide equal time to their daughters on their home computers.
- **Same Sex Pairings** – When possible, pair girls together to work on computer projects. Since girls focus more on the use of computers as tools, this pairing will help to portray computers as being tools to aid in socialization.
- **Appropriate Computing Curriculum** – Implement appropriate computing classes into the basic school curriculum. Ensure that the curriculum provides students with appropriate computing skills and interesting and challenging projects that will help prepare them for collegiate computing courses.
- **Recruitment** – Vigorously attempt to recruit more girls/women and their friends into computing courses.

## Computer Games

Recommendations for computer games focus on creating more software games oriented at girls. The hope is that if girls have software and games that they enjoy using, they will begin to have positive experiences with computers and may even consider CS as a career option.

- **Educate Game Makers** – Educate the game designers to their potential opportunities in the girl game market. Encourage game makers to create computer games specifically aimed at girls.

- **Educate Game Designers** – Educate game designers as to what girls really like in computer games and make them aware of the gender biases in game design.
- **Educate Parents** – Educate parents about gender biases in software and how to buy appropriate games and software that their daughters will enjoy. Encourage parents to insist on games aimed at girls. If there is a demand the game makers will listen.

## **Mentoring and Role Models**

Recommendations for mentoring and role models focus on providing mentoring programs and role models for girls and young women. This will help with the recruitment and retention of women in CS.

- **Support Mentoring Programs** – Many mentoring programs already exist for women in science. These programs should be supported and encouraged to bring in as many CS mentors as possible.
- **Implement Mentoring Programs** – Integrate with existing mentoring programs where possible or start mentoring programs at universities and high schools where they do not currently exist.
- **Organize Talks** -- Implement classroom visits and/or talks by successful women in computing positions.
- **Text Role Models** – Expose girls and young women to biographies and stories of successful women in computing (both current and historical).
- **Hiring Practices** – Evaluate hiring practices and implement those that support proactive recruitment of women in CS. These women will serve as role models for other women in their institution.

## **Self-Confidence**

Recommendations for self-confidence focus on activities that will bolster women CS student's impressions of their own accomplishments and abilities. By increasing their self-esteem, more women will stay in CS and possibly pursue higher education. There are also suggestions for increasing female students' self-confidence before college, thus increasing the chances they may become a CS major.

- **Enlist Instructors Help** – Inform K-12 instructors of the self-confidence issues related to gender. Teachers can make efforts to encourage girls to attend computing classes at every grade level, encourage the girls while taking the classes, and encourage them to pursue computing classes when they attend college.
- **Compare Standing** – It is believed that educators at all levels can improve female students' views of success by periodically showing women where they stand compared to their classmates and praising women for completing above-average work. This will help alleviate some of the negative effects of the male-induced competition. Also, departments should make sure that students,

especially female students, understand they do not have to be experts with every computer application they encounter (Bernstein, 1997).

- **Positions of Authority** – Female students should be allowed to hold positions of authority and power in computer labs at the high school and college level. This will enable them to obtain confidence in their abilities while gaining real-world experience. Having females in power available to answer questions will also help those women who are just beginning (Fossum & Haller, 1998).
- **Inclusion in Research Projects** – Computing faculty need to include female students in their research projects beginning at the undergraduate level. Programs such as Research in Undergraduate Institutions (RUI) may provide funds to help recruit female undergraduates (Pearl et al., 1990).
- **Modify Introductory Courses** – Institutions need to examine their courses, especially their introductory courses, to ensure that they are not unduly damaging to their women students' self-esteem (Fisher et al., 1999).
- **Unambiguous Feedback** – Educators at all levels should provide their students with unambiguous feedback concerning the quality of their work and refrain from engaging in discriminatory practices (Pearl et al., 1990).

## Computing Environments

Recommendations for computing environments focus on creating learning and working environments that are women friendly. In turn, this will make the environments more friendly to all students and workers.

- **Pleasant Computer Lab Environments** – Institute and enforce policies that ensure computer labs are clean, safe, and free of any material degrading to women.
- **Educate Lab Assistants** – Train and insist that lab assistants (in most cases these are students) are polite and fair to everyone in the lab. When they assist someone, they should explain why and what they are doing in an understandable manner.
- **All-Female Groups** – Start or encourage all women groups in an institute that can meet informally. Brown bag lunches centered around an agreed upon topic are an example. This will help the women at an institute to feel less isolated.
- **Classroom Assignments** – Create programming and other assignments with problems that would appeal to both women and men.
- **Provide Room to Express Milk** – Provide clean and private rooms where nursing moms can express milk. Installing outlets in the women's bathrooms is not a solution.
- **Train Management About Nursing** – Educate management to the benefits of moms nursing their children (e.g., breastfed babies are not sick as often which means the mom will not need to take off as much work). Encourage



management to not feel embarrassed by the topic and to support their nursing moms.

- **Provide Childcare for Employees** – On-site daycare or a site nearby should be supported. This will not only be good for the parents and their children but will also allow the employees to work more productively. They will not have to travel long distances for childcare or find unsatisfactory solutions.
- **Support Telecommuting** – Provide in-home offices for those employees with small children or long commuting distances. This will give the parents the flexibility and extra time (saved from no commute) to be better workers for the institute.
- **Support Flexible Hours** – Allow, when possible, the employees to work the hours as they can fit them in the day. This will give parents the needed flexibility to manage demands from their children and demands from their work.

## **Family and Teacher Encouragement**

Recommendations for family and teacher encouragement focus on educating parents, teachers, and counselors so they can encourage their daughters and female students to pursue technology courses. Many may not be aware of unintentional biases that exist. Awareness can help them to take proactive action to increase the numbers of girls interested in technology and computer science.

- **Educate Teachers** – Train teachers about gender differences and biases in the classroom. Encourage teachers to call on girls as often as boys and assign challenging tasks to both genders. Convince teachers to encourage girls to enroll in CS courses.
- **Educate Counselors** – Train counselors to encourage girls to pursue math, science, and CS courses and careers. Teach counselors about gender biases.
- **Educate Parents** – Encourage parents to provide computers in the household with equal access for all the family. Train parents about computer biases and encourage them to buy interesting and fun software for their girls as well as their boys. Teach parents about gender biases for CS so they can counteract them at home.

## **All-Female Environment**

Recommendations for all-female environment focus on supporting and creating all-female environments from computer clubs to all-female schools.

- **Create All-Female Groups** – Where possible create situations where girls or women can get together, with a focus on technology. This can take the form of a computer club, a weekly brown bag lunch session, or even a conference.
- **Create All-Female Classes** – If a school is co-ed, create some classes that are strictly for females. Ideally the classes should have a technology focus so the girls can learn about technology in a stress-free environment.

- **Support All-Female Learning Institutions** – Support all-female K-12 and college level institutions. Support can come in the manner of monetary, verbal, written, or encouraging your daughter or female students to attend an all-female school.

## Equal Access

Recommendations for equal access focus on providing K-12 learning environments where girls have as much access to computers as their male colleagues.

- **Educate Teachers and Computer Lab Instructors** – Educate K-12 computing instructors about the dynamics that occur in a computing lab setting among boys and girls. Help them to understand how to ensure that girls get equal time on computers and to watch for boys monopolizing the computers.
- **Same-Sex Pairings** – In computer labs, pair girls with girls to help ensure equal participation with the computer.
- **Support Public Sources of Computers** – Support public libraries and other institutions that provide free computer access to students. If some students in a class have no computers at home, encourage them to go to these public sites.

## Graduate School

Recommendations for graduate school focus on recruiting and retaining women in graduate school. Programs can be developed to expose women to graduate life and departments must take extra steps to assure a women friendly environment exists for their female graduate students.

- **Respectful Environment** – All faculty members should make sure to evaluate their own behavior. If the faculty and staff are disrespectful of women they will send the wrong message to other students (Bana & Hassoun, 1999).
- **Safe Environment** – Computing facilities should be well lit and in safe areas for women students to feel comfortable working at night. A university service should exist to escort women to their cars, bus stop, or living quarters at night.
- **Recruitment and Retention of Female Faculty** – Hiring and retaining female faculty provides role models for the female graduate students and possible female advisors. This is essential for women students to feel welcome and to obtain the feeling that they belong (Bana & Hassoun, 1999).
- **Women Speakers** – Invite women scientists to give presentations or give a seminar. They can serve as excellent role models.
- **Brown Bag Lunch** – Start a brown bag lunch for women graduate students. The focus could be on women in science and engineering or an interesting technical topic. Invite faculty to present their research.
- **Gender Equal Language** – Departments need to be sensitive when addressing the student body by using both “he” and “she” instead of assuming an entirely male student body (Bana & Hassoun, 1999).

- **Open Departmental Support** – Public support of women’s groups and issues by the department will open the eyes of all faculty and students. Departments should openly publicize interdepartmental courses on women in science and engineering (Bana & Hassoun, 1999).
- **Family Issues** – Be sensitive to the fact that some female graduate students may be starting families. Extra support in the form of encouragement, time off, or flexible hours should be given to pregnant women and women with small children.
- **Day Care** – Provide on-site subsidized daycare for graduate students with children.
- **Co-Ed Social Activities** – Encouraging social activities such as co-ed sports may promote a sense of belonging for women and men alike (Bana & Hassoun, 1999).

## **Balancing Work and Family**

Recommendations for balancing work and family focus on creating a support structure to help women cope with demands from their family and their work. Female faculty, as well as graduate students, are more than capable of handling both a career and a family if certain resources are at their disposal.

- **Affordable Daycare** – Universities and other institutions need to provide adequate daycare that is affordable. This would ideally be on-site. If not feasible, a convenient daycare center should be subsidized by the institution (Pearl, et al., 1990; Hassoun &Soha, 1999).
- **Job Security** – A cut or loss of salary, or a demotion should not accompany maternity leave longer than that given by the Family Leave Act (currently 6-8 weeks) (Pearl, et al., 1990; Hassoun &Soha, 1999).
- **Maternity Leave for Both Parents** – Maternity leave policies should include both parents. Men are wanting to take more of an active role in raising their children. They should be given this chance along with the women (Pearl, et al., 1990; Hassoun &Soha, 1999).
- **Slowing Tenure Clock** – Slowing of the tenure clock will allow both mothers and fathers to care for their children while still being productive at their job (Pearl, et al., 1990; Hassoun &Soha, 1999).
- **Part-Time Work** – Institutions should allow part-time work to accommodate those new parents who need more time at home for a few years. Universities should consider part-time enrollment options for students with family obligations with extensions on the dates credits expire (Pearl, et al., 1990; Hassoun &Soha, 1999).
- **Flexible Hours** – Institutions should have flexible hours for its parent employees to accommodate the trips to the pediatrician, pediatric dentist, and other appointments that only occur during the work week.

- **Support Telecommuting**– Institutions should strongly consider setting up a home office for those employees with small children or other family issues that require them to be at home more. This should include an up to date computer and broadband Internet access. Telecommuting should be supported by upper management.

## Societal Influence

Recommendations for societal influence focus on reversing some of the negative impact society has on discouraging girls to remain in computer science.

- **Make Computing Cool for Girls** – Develop programs in schools that allow girls to enjoy technology and market these programs as being cool and exciting (rather than boring and geeky).
- **Involve Parents** – Get parents involved in working with their daughters on the computer. Encourage parents to send their daughters to computer camp and enroll them in computer classes and clubs.
- **Change the Image of CS** – Change the negative stereotype of computer scientists from the white nerdy antisocial male to social interesting people of all genders and races. Change the image of computer science as being boring and geeky to one that is fascinating and full of new ideas and challenging problems.
- **Give Girls more Self-Confidence** – Start and support programs that give girls more self-confidence in themselves in being able to tackle math, science, and technology.

## Other Forms of Discrimination

Recommendations for other forms of discrimination focus on three areas that do not fit into the other previous categories: subtle but constant, invisibility syndrome, and hiring to keep women down.

- **Open Door Policy** – Encourage upper management to have an open door policy where they make employees (or students) feel welcome to complain. The complaints should be taken seriously and looked into, no matter how trivial.
- **Reduce Discrimination in the Work Environment** – No matter how trivial, make changes in the work environment to decrease gender discrimination. Every small change will add up to making the environment much more women friendly.
- **Implement Policies to Increase Visibility of Women** – Policies to increase the visibility of competent women in CS should be implemented. Proactive action needs to be taken to ensure that women are invited to give key note addresses, invited to be on editorial boards, included in conference organization, included in edited books and so on.

- **Fair Hiring Practices** – Technology corporations should review their hiring practices. There should be an attempt to hire more women but only qualified women.

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