Sundials in the Shade

A Study of Women's Persistence in the First Year of a Computer Science Program in a Selective University

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A DISSERTATION

in

Higher Education Administration

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Doctor of Education

2005

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Supervisor of Dissertation

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Dean, Graduate School of Education

DEDICATION

This dissertation is dedicated to the fourteen women in this study group. May the sun shine on you.

ACKNOWLEDGEMENTS

First and foremost, I thank my family for their support throughout this process, especially my husband, Ken, who has been so generous and loving. I hope that my work on this project helps instill in my children, Nora and Kip, an appreciation for education, as my parents, Marian and Ralph Manco, have inspired in me.

I thank my dissertation supervisor, Dr. Ursula Wagener, for her unwavering support and tireless counsel throughout the numerous drafts of this dissertation. Additionally, I thank my committee members, Dr. Marvin Lazerson and Dr. Norman Badler, for their interest in my work and their expert guidance and insight throughout this process.

I am indebted to Dean Eduardo Glandt, the faculty, administrators, staff and students in the School of Engineering and Applied Science of the University of Pennsylvania, who gave generously of their time and perspectives on the issues in women's persistence in computer science. I thank, especially, Jackie Caliman for sharing with me her substantial knowledge of the undergraduate programs and students in computer science, and Fernando Pereira, Chair of the Dept. of Computer and Information Science, for making this study possible.

Finally, I thank the fourteen women participants in this study for sharing openly and honestly their experiences with me. You are talented, passionate and energetic individuals who will be successful in whatever you choose. I have the greatest admiration and respect for each one of you.

ABSTRACT

SUNDIALS IN THE SHADE; A STUDY OF WOMEN'S PERSISTENCE IN THE FIRST YEAR OF A COMPUTER SCIENCE PROGRAM IN A SELECTIVE UNIVERSITY

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Currently women are underrepresented in departments of computer science, making up approximately 18% of the undergraduate enrollment in selective universities. Most attrition in computer science occurs early in this major, in the freshman and sophomore years, and women drop out in disproportionately greater numbers than their male counterparts. Taking an ethnographic approach to investigating women's experiences and progress in the first year courses in the computer science major at the University of Pennsylvania, this study examined the pre-college influences that led these women to the major and the nature of their experiences in and outside of class with faculty, peers, and academic support services. This study sought an understanding of the challenges these women faced in the first year of the major with the goal of informing institutional practice about how to best support their persistence.

The research reviewed for this study included patterns of leaving majors in science, math and engineering (Seymour & Hewitt 1997), the high school preparation needed to pursue math and engineering majors in college (Strenta, Elliott, Adair, Matier, & Scott, 1994), and intervention programs that have positively impacted persistence of women in computer science (Margolis & Fisher, 2002).

The research method of this study employed a series of personal interviews over the course of one calendar year with fourteen first year women who had either declared on intended to declare the computer science major in the School of Engineering and Applied Science at the University of Pennsylvania. Other data sources were focus groups and personal interviews with faculty, administrators, admissions and student life professionals, teaching assistants, female graduate students, and male first year students at the University of Pennsylvania.

This study found that the women in this study group came to the University of Pennsylvania with a thorough grounding in mathematics, but many either had an inadequate background in computer science, or at least perceived inadequacies in their background, which prevented them from beginning the major on an equal footing with their mostly male peers and caused some to lose confidence and consequently interest in the major. Issues also emanated from their gender-minority status in the Computer and Information Science Department, causing them to be socially isolated from their peers and further weakening their resolve to persist. These findings suggest that female first year students could benefit from multiple pathways into the major designed for students with varying degrees of prior experience with computer science. In addition, a computer science community within the department characterized by more frequent interaction and collaboration with faculty and peers could positively impact women's persistence in the major.

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INTRODUCTION

Women account for less than 20 percent of undergraduates in selective computer science programs nationally. In 2000, a National Science Foundation report forecasted that Information Technology jobs would increase by 75 percent between 2000 and 2010, accounting for 15 percent of all new jobs in the American economy. Yet in the year 2000, women held only 24 percent of degreed IT positions. Consequently, women are excluded from participation in a growing field, now an essential partner in disciplines as wide ranging as medicine, business, education, the arts and national defense.

The metaphor of the leaking pipeline is commonly employed to describe the defection of women from the study and practice of computer science. Few girls and fewer women are attracted to the field and women's numbers decrease at every stage of their education from middle and high school through college and graduate school and finally to the professional and academic workforce. Women's limited participation in computer science is particularly surprising and disturbing because women earn over half of all bachelor degrees and nearly half of the bachelor degrees in science and engineering. However, in 1998, women earned only 26 percent of the undergraduate degrees awarded in computer science, a decline from 37 percent in 1984 (NSF 2000). During this same time period, all other academic majors experienced increases in the participation of women, with most majors enjoying substantial increases. Women have buoyed enrollments in every science, mathematics and engineering major except computer science, and this situation is a major contributing factor to the nation's current inability to graduate enough computer science majors to keep pace with the demand for IT workers.

Women's under representation in computer science has evoked a spectrum of speculation concerning the causes from academicians, industry professionals and researchers ranging from suspicion that the field is inhospitable to women, to claims of innate biological differences in men and women that are responsible for differences in the aptitudes of the sexes, to assumptions based on the environmental effects of cultural differences in men's and women's socialization which inhibit women from participating

in the physical sciences and engineering. As yet, there are no conclusive answers for why women are under represented in the field of computer science, or why women drop out of computer science majors in disproportionately greater numbers than their male counterparts. Clearly, in the current situation women are missing out on a great proportion of economic opportunities in the careers and salaries that IT provides. The nation is also losing the contributions, ideas and viewpoints of almost half of the population. Benjamin Franklin described wasted strengths as sundials in the shade. This study investigated these questions by studying the experiences of freshman and sophomore women as they commenced their study in the major at the University of Pennsylvania.

BACKGROUND AND PROBLEM STATEMENT

The Department of Computer and Information Science (CIS), one of six departments in the School of Engineering and Applied Science (SEAS) at University of Pennsylvania, comprises approximately 20 percent of the students within the school. CIS is an important department because of the projected growth in the technology industry, which will increase the demand for computer science majors. In addition, CIS draws more students who enroll in computer science courses from Penn's broader student body than any other department within SEAS.

During the technology explosion of the late 1990s, CIS experienced tremendous growth, more than doubling in majors. The technology boom focused students' attention on the considerable career opportunities available in the field of Information Technology. The School of Engineering and Applied Science responded to this interest by ramping up the department, adding twelve new faculty within five years, hiring a new Chair with an impressive research record in industry, and building a state-of-the-art facility to house the growing department. With a larger faculty and premiere facilities, CIS was poised to increase research funding, improve the breadth and quality of its academic programs and compete with the top computer science departments in the most selective schools.

Although SEAS' records do not indicate where students go after they leave the Dept. of Computer and Information Science, enrollment and graduation records show that CIS graduates close to the same number of students that the department admits. The large transfer-in of students into the department in

recent years has masked the attrition out of the department. Women comprise approximately 20 percent of the CIS incoming class of declared majors each year. However, the proportion of women in a class decreases from the freshmen to the senior year because more women transfer out each semester than transfer in. For example, in the academic year prior to this research study, 5 of 11 students or 55 percent that switched out of CIS from November 2002 through May 2003 were women. Conversely, only 1 of the 14 students or 7 percent who transferred into CIS during this same time period was a woman. Women made up 25 percent of the introductory computer science course CSE 120 enrollment in fall 2002. By the midterm, 6 of the 13 or 46 percent of the students who dropped out of CSE 120 were women. By January 2003, women comprised only 19 percent of CSE 121, the second course of the first year sequence

The 2003-04 academic year presented an opportune time to embark on a study of the issues behind women's retention in the CIS major. With the onset of the technology bust, the CIS department, like most other departments of computer science, experienced a drop in applications to its undergraduate programs. In the aftermath of the technology bubble, enrollment in the 2003 incoming class dropped from the previous two years and the faculty focused attention on CIS student persistence. The current enrollment decline experienced by CIS is characteristic of the current situation in most computer science departments nationwide. Recent survey results from the Higher Education Institute at the University of California at Los Angeles (HERI/UCLA) show that the popularity of computer science as a major among incoming freshmen has dropped by 60 percent in the last four years. Moreover women's interest in majoring in computer science fell 80 percent between 1998 and 2004, and 93 percent since its peak in 1982, double the drop in men's interest. This alarming drop in women's interest in computer science is largely responsible for the decrease in overall computer science degree production While enrollment in most other majors has been boosted by the influx of women into higher education over the past three decades, the opposite situation has occurred in computer science. Computer science departments cannot produce IT workers to match the projected demand without increasing women's participation in undergraduate computer science majors (Vegso, 2005).

During the course of this study, CIS boasted four women in the standing faculty, two of whom had joined the department in the last four years, and the chair of the department had appointed women in three of the four Lecturer positions in the department. However two of the four women in the standing faculty

left the University of Pennsylvania at the end of the 2004-05 academic year. The female undergraduates in the department spontaneously organized themselves in spring 2003 to meet the challenges women face in the major. Their organization, Women in Computer Science (WICS), has already demonstrated that it intends to meet the issues of undergraduate women in the major head on. Drawing large percentages of the undergraduate women in the department at their events, as well as many male undergraduates, WICS has hosted faculty to discuss curriculum and women from industry to develop networking opportunities for the female students in the department. The female graduate students have also organized themselves by breathing new life into the department's CISters organization. The goal of CISters is to help graduate women know each other, since they are dispersed throughout the department's research groups.

As department manager and assistant to the chair, I am a CIS insider. Through my position and with the permission and assistance of the department chair, I have access to the students, faculty, teaching assistants, SEAS administrative staff in the Academic Programs Office and student academic records. I have participated in the life of the department through interacting with both faculty and students. For the past three years, I have served as the advisor to WICS and I have applied for and received grants from the Trustees Council of Penn Women to help fund WICS activities. Along with three undergraduate women, two graduate women and Lecturer Jean Griffin, I participated in the 2003 Grace Hopper Celebration of Women in Computing conference in Chicago. I had the honor of presenting the prestigious Alice Paul Award, given to the female student who had made the most impact on improving the lives of women at Penn in 2004 to the cofounder of WICS, Radhika Gupta, at the annual awards ceremony of Penn ProWomen hosted by then President Judith Rodin. I have also worked with students in the Dining Philosophers (DP), the Association of Computing Machinery's student chapter, the Engineering Dean's Advisory Board (EDAB) and the students from the Science and Technology Wing (STWing), a residential community composed of students who share an interest in technology, in planning events to bring students and faculty together. Through these experiences, I have built trust and friendships with the CIS students, which was instrumental in gaining student participation in my study.

The University of Pennsylvania is in an ideal position to embark on an effort to improve the experience and retention of women in computer science. Penn is one of the most selective research universities in the world with an undergraduate admission rate of 21 percent and a yield of 62 percent of

accepted students, and Penn's students are among the finest in the nation. The University of Pennsylvania is committed to encouraging and supporting diversity in faculty and students. Encompassing twelve schools, the environment of the university is multidisciplinary. Penn allows students to study in more than one school, making Penn appealing to students who are interested in technology and engineering, but also in the liberal arts, fine arts or business. Engineering students typically select a dual major or minor in the College or the School of Fine Arts, or a dual major in the Wharton School. The School of Engineering and Applied Science successfully graduates 90 percent of its students within 5 years of matriculation. In addition, Penn Engineering's small size makes it possible for the school to provide a personal atmosphere and a welcoming, inclusive environment for its students.

RESEARCH QUESTIONS

Currently women are underrepresented in the Dept. of Computer and Information Science at Penn, making up approximately 18 percent of the undergraduate enrollment. How are these women faring as they pursue the undergraduate degree? Are they satisfied with their academic experience? What support do they require? Are their academic, social and emotional needs being met by the Department, the School of Engineering and Applied Science, and the broader Penn community? Why or Why not? How can their early experience in the major be modified or restructured to improve their retention in the major?

The following research questions explored these issues and provide valuable data to the Dept. of Computer and Information Science faculty, as well as school policy makers, enrollment management professionals, admissions officers, learning support specialists, and student life professionals on how and at what cost they can support the progress toward degree and success of women undergraduates majoring in computer science. Since most attrition in Computer Science occurs early in the major, in the freshmen and sophomore years, this study explored students' first experience with the major in the freshman/first required course sequence, CSE 120 Programming Languages and Techniques 1 in the fall semester and CSE 121 Programming Languages and Techniques II in the spring, to shed light on the impact that this academic experience had on students' resolve to persist in the major.

1. What familial, educational, social, professional, personal and economic influences does the student feel impacted her decision to major in Computer and Information Science? What was her experience with computer science prior to enrolling at Penn? Does she believe that her prior experiences prepared her for the CIS major? Why or why not?
2. How is the student financing her undergraduate studies and what are the issues?
3. How have her initial experiences in CSE 120, the first required computer science course for majors, and other computer science courses influenced her decision to select and/or persist in the Computer and Information Science major? Is she making good academic progress in the major, as defined by her GPA and her desire to persist? What are the academic and non-academic challenges to pursuing the major? How are these addressed?
4. What have been the student's experiences with CIS faculty, teaching assistants and department and school staff inside and outside of class, and what role does the student believe these experiences play or do not play in her academic success?
5. Has the student been involved in a CIS study group? Has she been involved in the Penn Mentoring Program? If not, why not? If yes, what impact did the study group and/or mentoring have on the students' academic pursuits?
6. To what extent is the student an integral part of student life? Has she been involved with the Women in Computer Science group? With other student organizations within the school? With a Greek sorority on campus? What have been her experiences with her peers? Does the student believe these experiences play a role in academic success? If so, why? What other influences play or do not play a role in academic success?
7. What are the student's long-term professional and academic goals, and how does the CIS major play in these goals?

The conclusions drawn from this study inform the Dept. of Computer and Information Science at Penn, as well as other similar, departments and schools of computer science about the effectiveness of existing academic, financial and social student support services in promoting female students' retention in the major, and the critical support still needed to encourage persistence in the major for this population.

METHODOLOGY

Overview

My methodology consisted of a qualitative approach to addressing my research questions concerning the experiences of women who are in the early stages of pursuing a computer science degree at a selective university, and provides reliable data, which tell the personal stories of these women. The purpose of this study was to understand the challenges these women face in studying computer science, the nature of their experiences, the sense they make of these experiences, and how their relationships and associations with faculty and peers influenced their decisions. My study informs institutional practice concerning the support systems these students need to be successful. By focusing on each student's personal story, I gained a contextual understanding of the influences that these students' feel led them to the computer science major, their early experiences in navigating and mastering the CIS curriculum, their academic and social experiences with faculty, other teaching staff, and peers in the major, and how these experiences impacted their persistence and success.

Seymour and Hewitt (1997) chose an ethnographic approach to studying persistence in their study of science, math and engineering majors resulting in their book Talking About Leaving: Why Undergraduates Leave the Science. The authors explain why they chose an ethnographic approach to answering their research questions on why able students who begin in science, math and engineering majors fail to persist, and why the authors ruled out the use of standardized interview instruments. "We adopted an ethnographic approach which was grounded in the assumption that undergraduates are expert informants who are well-placed to describe the strengths and limitations of their educational experiences: where students abandoned their intention to major in an S.M.E. (science, math, engineering) discipline, only they can explain how they weighed particular elements in the network of events leading to their decision…Throughout our account, we have followed the ethnographic tradition of presenting our analysis through the accounts of the participants themselves" (Seymour & Hewitt 1997, 13-30).

Maxwell (1996) provides an excellent framework for structuring a qualitative, contextual methodology. Maxwell lays out four components to structure a qualitative study. The first component is

establishing the research relationship. Because I am the Department Manager of Computer and Information Science, and Assistant to the Chair of this department, I have daily access to the CIS students and faculty. I became involved in the fledgling student organization, Women in Computer Science (WICS), which the students organized entirely on their own in the 2002-2003 academic year. I attended the WICS meetings and assisted the group in gaining the participation of the department chair, faculty and SEAS administration. In October 2003, I participated in the Grace Hopper Celebration of Women in Computing Conference with five undergraduate and graduate students and a department lecturer. The Grace Hopper Conference is a biennial conference for researchers, faculty, and students, which showcases the contributions of women to the field of computer science. In 2003, 2004 and 2005, I successfully applied for a grant on behalf of WICS from the Trustees' Council of Penn Women, securing $2,500 each year to fund WICS' programs in each academic year. I have also participated in the female graduate student and faculty organization, the CISters, and have brought graduate and undergraduate students together over issues of mutual interest. This involvement has helped me to establish credibility with the faculty and students in the CIS department.

Getting started

I have discussed issues of academic persistence of under represented groups as a topic for a study with my doctoral advisor since the fall of 2000. In the fall of 2002, we corresponded specifically concerning my proposed study of the persistence of undergraduate women in computer science. Throughout the fall '02 and spring '03, I searched for previous research on women's retention in science, math and engineering, and specifically in computer science, to clarify my ideas and goals for the study. In the spring of 2003, with the assistance of my advisor, I developed my research questions.

With the approval of the department chair, I conducted one trial focus group with the students in CSE 120 in December 2002. The students were studying together for their final exam in the lab, and the Lecturer who coordinated the CSE 120 labs and I invited the women students to a conference room for snacks and a study break and informal discussion. Thirteen women participated in the pilot. The discussion centered around one question which we asked the group: Did your experiences in CSE 120 positively or negatively affect your intention to persist with the computer science major, and why? The

group of freshmen and sophomore women engaged in a spirited discussion on their struggles with homework, their fears about the impending exam, and their strategies for study. They clearly enjoyed sharing their feelings with the Lecturer and me. However, the general feeling in the group was fear for their ability to succeed in the CIS major after their experience with CSE 120. After approximately 45 minutes of discussion, I described to the group my plans for a study of women's satisfaction with and persistence in the computer science major. All 13 students said they would participate in my study if asked. I took notes on the students' discussion during the pilot focus group, maintaining the anonymity of each participant. After I transcribed these notes, I shared them with the Department Chair.

In fall '02, 38 women and 115 men were enrolled in CSE 120. After the midterm, I checked the course records and learned that six women and seven men had dropped the course. I discussed with the department chair my interest in understanding why these students had dropped. With his approval, I emailed all 13 students who dropped after the midterm asking them why they had dropped the course. I received responses from two women and three men. In January '03, I reviewed the enrolled student record for CSE 121 and cross-referenced it with the December enrollment record for CSE 120. Of the 32 women who completed CSE 120, only 21 had enrolled in CSE 121, the second required course in the computer science major. I wondered what had happened to the other 11 women students. I emailed all 11 women students and asked why they had not enrolled in CSE 121. I received four responses. One student was enrolled in the Wharton School and did not need CSE 121. Another was a graduate student and she had taken CSE 120 as an elective. One student emailed me her telephone number and asked me to call her. We talked on the telephone for approximately 20 minutes. She was eager to discuss her early experiences at Penn, her problems with the course, and her indecision regarding the next step she would take in her academic program. The fourth student emailed me and explained that although she had done ok in CSE 120, the workload had made her physically ill, and her parents had convinced her over the break to drop the CIS major. Again, I shared the students' responses with the department chair, maintaining the anonymity of the students. My pilot questions to the students who did not persist after the midterm and the end of the course, and my trial focus group convinced me that I could gather meaningful data on the experiences of women students if I could develop a research relationship over time with women who attempted the computer science major, both those who succeeded and those who opted out.

Choosing My Sample

Maxwell's second step for structuring a qualitative methodology is determining a sampling method. I chose the introductory course in the computer science curricula from which to draw my sample of women students. CSE 120-121 Programming Languages and Techniques I and II is a course sequence taken by students in the fall and spring semesters of their first year in the major, and is considered the "make or break" course for persistence in the major. A student may not take another computer science course before taking this course sequence without the expressed permission of the department chair. The chair teaches the fall course and he gave me access to the students to draw a sample for the study. Fall '03, the semester that this study commenced, was the second time that the chair taught this course, and he was aware of and concerned about the retention issues that accompany it. Although a background in programming is not required for the first course, students in previous years have found themselves at a distinct disadvantage in comparison to their peers when they do not have previous programming experience. This disadvantage is corroborated in the literature of computer science education (Margolis & Fisher, 2002). In June '03, the department had the names and records of all incoming freshmen students, and the enrolled students for the first required course in the CIS majors, CSE 120 Programming Languages and Techniques I. There were 24 women enrolled in this course. With the assistance of my committee chair, I developed a letter of informed consent for students who agreed to participate in my study. In the first week of class in fall '03, I addressed the CSE 120 class and told them about my study. I invited the women in the class to a lunch following the class to learn more. Eighteen of the 24 women attended my lunch and 14 of these agreed to participate in my study. In the two weeks following the lunch meeting, I contacted each of these students by email and arranged an individual appointment with them in Levine Hall. At the first individual meeting, each student signed the letter of informed consent prior to the interview.

Maxwell states that for qualitative research, most sampling is purposeful sampling or criterion-based selection. For a small-scale study, purposeful sampling achieves representativeness, since cases, individuals, or situations are deliberatively selected that are known to be typical. Purposeful sampling also captures the heterogeneity of the population, since selection may adequately represent the entire range of variation, rather than only the typical members or some subset of this range (Maxwell, 1996, 70). In the

summer of 2003, I reviewed the admissions and enrollment reports on the new female students in the files, housed in Department of Computer and Information Science Office, and purposefully chose students who met the following criteria:

Gender—Female

New to the Computer and Information Science department

Enrolled in CSE 120 Programming Languages and Techniques I

A pool of 24 women consisting of freshmen declared CIS majors, curriculum deferred freshmen, new transfer students to CIS, and sophomores who had declared the computer science major in spring '03 and had not yet taken a computer science course qualified for my study. (Curriculum deferred students are those who enter SEAS without selecting a departmental major. A high percentage of curriculum deferred students who take CSE 120-121 have the intent to major in CIS.) From these 24 students, 14 women agreed to participate in my study. The computer science retention statistics indicated that there was a good possibility that one or more women in my study group would switch out of computer science during the course of the study. To answer my research questions, it was just as important to study the subsequent experiences of those women who left CIS within the first year as those who persisted. Therefore, I worked with the students in my study group over the course of one year and followed their progress at Penn, regardless of whether or not they completed CSE 120 and proceeded, as planned, to CSE 121. It was also important to obtain the point of view of the male students in the CSE 120-121 course sequence on the academic and social issues which impact persistence early in the major. At an advising meeting for CSE 120 students in fall '03, I addressed the group and randomly selected fourteen male students to meet with in a focus group. Nine male students agreed to participate and subsequently I met with them in a group for one hour in October '03. I met with seven of these men again in a two-hour dinner and focus group with the women study participants in spring '05. My interview questions for the men in the fall focus group covered the same issues and items that I covered in the in-depth individual interviews with the female students.

Collecting the Data—the Interview Plan

Maxwell's third step to structuring a qualitative methodology is determining data collection methods. I gathered information from the students' files on the students' previous educational background and SAT scores. I conducted three individual interviews with each student in September/October, November/December, and February. The 60-minute personal interviews took place in a department office or conference room in Levine Hall. To gain the male CIS students' perspective on the issues impacting persistence in the major, I held an all-male focus group in October '03 and a co-ed focus group in April '04. I held two all-female focus groups in October '03 and again in September '04. I also gave each of the fourteen women a journal and asked them to record their experiences in the computer sciences courses throughout the academic year. Margolis & Fisher (2002) suggested giving a reward to students to encourage the students to keep a journal. They gave their students $5 for each journal entry and this incentive did increase the students' journaling activities. I gave the students who kept a computer science journal a $25 gift certificate to the university bookstore in exchange for their journals. Nine women wrote experiences concerning computer science in these journals and turned them in to me in April '04. In addition, I gathered data on the support systems available to CIS students at Penn by interviewing two CIS women faculty, the CIS chair who teaches CSE 120, the faculty member who teaches CSE 121 in spring, two additional male faculty members, the lecturer in charge of the CSE 130-131 labs that accompany the lecture courses, three teaching assistants for the labs, two CIS female graduate students, two female Ph.D. computer scientists affiliated with the CIS department, the CIS Undergraduate Chair, the CIS Undergraduate Coordinator, the Associate Dean for Undergraduate Affairs, the SEAS Director of Faculty Advising, the SEAS Academic Programs Director, the SEAS Associate Director of Student Affairs, the Coordinator of the Penn Mentoring Program, the Director of Learning Resources, the Director of the Dept. of Academic Support Programs, the Coordinator of Penn Tutoring, the SEAS Associate Director of Admissions, the University Associate Dean of Admissions, and the Associate Director of the Digital Media Design program. I interviewed Carnegie Mellon Professor Lenore Blum and Carol Frieze, Associate

Director of Women@SCS, Carnegie Mellon University, because of the remarkable strides made at CMU in recruiting and retaining women in the School of Computer Science.

I developed formal questions based on my research questions for the SEAS and CMU faculty and staff, and each round of personal interviews and focus groups with the students. These questions were the same for each student to compare their responses. They were supplemented by individual questions based on the student's file and previous interview. Open-ended questions directed the interviews, and I encouraged students, faculty and staff to digress and expound on their answers. I probed the students through follow up questions when we discussed particularly interesting and relevant issues. I recorded all sessions with the students to capture accurately their responses and digressions, took notes during the interview on body language, physical appearance and disposition of the students, and transcribed the tapes and notes within 48 hours of each session. I maintained digital audio computer files of the student interviews, which I stored on my computer. Digital audio files simplified the transcription process and also made it easy to organize the audio files and selectively re-listen to specific files for student tone and voice. When needed, I followed-up these interviews and focus groups with emails to specific students to clarify my understanding of the data. As mentioned earlier, I supplied each female student in the study with a personal journal and requested that they record their experiences, feelings and reactions throughout the year.

Student records: I have access to the students' records which contain useful information, including the name, address, telephone number, email address, gender, ethnicity, degree program, SAT scores, prior Penn grade reports, AP credits, college GPA and advisors' notes.

Personal interviews: I used the personal interview technique with open-ended questions to allow the students to tell their personal stories. By asking students to describe their experiences and behaviors, I endeavored to gain an understanding of the meaning and significance of their experiences and behaviors. After each round of interviews, I compared the various student responses to my questions and recorded my findings.

Interview Protocols:

1. Interview one protocol focused on getting to know the student better, explaining the study and its goals, gathering background information on the student's familial influences and high school experiences, including prior experience with computing, to construct a picture of how the individual developed as a student, who or what influenced this development, the evolution of the student's interests in computers, her extracurricular activities in high school, the influence of career expectations, and how the student's background and experiences brought her to enroll in the CIS major at Penn. Were there any computer scientists or engineers in her family? What were the sibling dynamics in the family? I also probed for sources of emotional support from family, teachers, and friends for the computer science major. I asked how the student was financing her undergraduate studies, the student's financial aid package and the financial aid process that she experienced. How had her transition been to Penn? Had she formed new friendships both within and outside of the major? How had she adjusted to her dorm? Did she hope to join a sorority? What academic advising had she received thus far?

2. The protocol for the second interview focused on academic challenges in CSE 120 since the student was past the midterm and into the second half of the semester. Questions probed the student's response to academic challenges, whether she sought support, the nature of that support (faculty, university services, other students, outside assistance) and the likely academic outcomes. If the student dropped CSE 120 after the midterm, I probed for the reasons why, and how she came to make the decision to drop. I asked her how she felt about her decision and her experience in the course, and what shape and direction her academic plans were taking.

For students who stayed in the major, I probed their relationships with faculty, both in and out of class, and other students. What was the nature of these relationships, and what type of academic support were they providing? I asked the student to describe her experiences with faculty, lecturers and teaching assistants, whether good or bad. What was the nature of the student's interactions with her peers? Did these interactions often extend from class projects, labs and assignments? Were these relationships a source of academic support and how? Was she involved in a CIS study group? Penn mentoring? WICS? What were the student's expected academic outcomes for the semester?

3. The third interview took place in February of the second semester. If the student persisted, she was enrolled in CSE 121. I questioned these students about their academic results in CSE 120. How did she feel about her first college experience with computing? Did it heighten her interest in the major and strengthen her resolve to persist? Why or why not? If the student was not enrolled in CSE 121, I probed for the reasons why? Was she having academic difficulties? What was the nature of the difficulties? Was she drawn to another major? What aspects of another major interested her? What were her intentions in the CIS major at this point? What shape and direction were her academic plans taking?

I asked the student to describe what she liked and did not like about programming, the subject matter of the introductory courses, and what the student liked most and least about computer science. I probed her perceptions of the atmosphere in the department. Did she feel that she fit in? Why or why not? What was her opinion of the other students in the department? What was it like to be a woman in computer science at Penn? I focused the student on talking about her academic strengths, preferences and learning style. What was the extent of the student's participation in the university community outside of classes? Had she joined university organizations?

I also asked the students about their career aspirations, perceived utility of CIS courses and the degree, progress in CIS courses to date, and satisfaction with the major. What did the student perceive to be the strengths and weaknesses of the CIS program? What suggestions did she have for improving the program and curriculum? What were the student's expected academic outcomes for the semester? What had been her experience with the academic advising process? Had it been helpful? What had been her experience with lecturers and teaching assistants? Had they been helpful? Why or why not? How did her friendships with peers develop over the course of the year? Had she become involved with WICS? What had been the nature of her involvement and what impact did it have on her progress in the major?

Focus groups: The focus group technique is a valuable research tool for obtaining in-depth information on a specific topic through a group discussion with relatively homogeneous participants in a relaxed atmosphere. The focus groups were 60 to 90 minutes long. The focus groups elicited discussion among the participants, with little input from me as moderator than to keep the conversation flowing and to

introduce topics through questions. The focus groups elicited the participants' perceptions, feelings and attitudes, and each student had the benefit of the other group members to influence and respond to her comments. Listening to others assisted and encouraged each participant to formulate their own viewpoints. Thus the benefit of the focus groups was to create a synergy from the group as a whole, which drew more expression of feelings and experiences from each individual participant. The participants also benefited from the discussions by drawing strength from each other, thereby validating their own experiences and feelings. The focus group gave me as moderator the flexibility of probing further by following the participants' determination of the direction of the discussion.

The protocol of the first focus group involved the students' perceptions of the academic challenges posed by the CIS major and how they met these academic challenges. Were the university's sources of support, (advising, faculty, other students, organizations, learning support, counseling support) effective in meeting the academic challenges? What were the nonacademic challenges facing these students? Were there any issues stemming from the minority status of women in the department? What were the students' perceptions of the school and department environment? What interpersonal dynamics developed when these students assembled in a group situation?

The protocol of the second focus group involved the students' academic outcomes for the year, progress to degree, career aspirations, perceived contribution of skills, knowledge and credential from achieving the degree, long-range plans, and satisfaction with the CIS program. What camaraderie had developed in this group? Did the group, itself, serve as a source of support for the students? Had any other groups, such as WICS, the DP or STWing been helpful? What were the students' suggestions for improving the CIS program? Were their issues around curriculum that needed to be addressed? What suggestions did they have for improving the curriculum?

Interviews with faculty and higher education professionals at Penn:

I interviewed CIS faculty to gather information on the advising process in the CIS major. All freshmen are assigned an academic advisor from the CIS standing faculty when they enter the department. The professor becomes the student's advisor for the duration of her time in the department, unless the student requests a change from the undergraduate coordinator. I asked the advisors how often they saw

their advisees, how long they spent with them, and what was discussed in an advising session. I also asked the faculty if they have had any involvement with undergraduates through research projects, and if so, to describe their experience. What was their viewpoint on how the department can support the female undergraduates?

I interviewed the department chair and the undergraduate chair concerning changes they are planned or foresaw in the curriculum in the major.

I interviewed student services staff in Academic Programs, Penn Mentoring, Dept. of Academic Support Programs, the Penn Learning Resources Center and the CIS Undergraduate Coordinator concerning the services for financial aid, learning support, and student life that are in place or planned for CIS students. I asked which services the students use and how often they use these services. In their opinion, what problems do the CIS students, particularly the women, face, and to what extent can these problems be addressed? I probed the Academic Program Director for trends in the admissions and retention of CIS students, particularly women. I also asked about the Pre-Freshman program in summer 2003, which CIS participated in for the first time. Was the program a success? What changes are planned for next summer? What other programs were on the drawing board that might improve students' success in SEAS?

I interviewed the Associate Dean for Undergraduate Affairs, the faculty Director of Academic Advising, and the Director of Academic Programs to get their viewpoint on how SEAS can best recruit and retain women students? Is SEAS involved with outreach to high schools? How do other SEAS departments participate in the recruitment and retention effort? Are other departments involved in recruiting functions such as Penn Preview? What involvement by departments would they like to see? What was the scope and impact of the pre-freshman summer program and what changes were planned for this program? What changes would they like to see in the academic advising process? How useful did they think organizations like WICS are to students, and what recommendations do they have for WICS?

I interviewed Lenore Blum, faculty advisor for Women@SCS at Carnegie Mellon University, and Carol Frieze, Associate Director of Women@SCS regarding recent developments on the admissions and retention of women at CMU. Which programs were working and which had been discarded? What policy changes was CMU considering? What curricular directions was the School of Computer Science pursuing

because of the increased numbers of women in the School of Computer Science? How have the greater numbers of women changed the school? What advice could they give to Penn?

Data Analysis

Maxwell's fourth step to structuring a qualitative methodology is selecting data analysis strategies and techniques. Through reading and rereading the interview transcripts, observation notes, academic transcripts and my own personal memos, I contextualized the data, considering each student's accounts in relationship to that student's individual circumstance. Contextualizing the data helped me to understand the unique experiences of each student, but it did not render meaning that could help me contribute understanding to the situations of women, in general, who are studying for a computer science degree. Therefore, I also looked for patterns in the data, such as issues, reactions and responses that were common to most or all of the students, to develop themes about what was going on for these people in this situation. I read the data for "voice" to separate my own biases and opinions from the data, and allow the students true feelings to surface. I used a case study approach to tell the students' individual stories, their triumphs and their failures, as they worked toward achieving the bachelor's degree. I also looked for other sources of information, such as the faculty advisors and academic and administrative staff, to ensure my understanding of the data.

Ensuring Validity

A longitudinal Approach: Gathering data from my study group over one year to answer my research questions illuminated changes that these students had to undergo in their viewpoints and opinions of their progress in the undergraduate program. Collecting data longitudinally also allowed a pattern of the students' academic experiences, successes and obstacles to unfold.

Triangulation of the data: Throughout the academic year, I scheduled interviews with Penn Computer and Information Science faculty and academic and student support staff. The information gathered from these diverse sources triangulated the data from the student interviews and focus groups, and contributed material from which I drew my analysis. The students' own words, contained in their journals and their emails to me, also provided useful material to triangulate my data.

Valid Description: By recording my interviews, writing summaries of each interview, transcribing the recordings immediately following the interviews, taking copious notes, and writing memos on my observations, I was able to validly describe the students' experiences as they related them to me.

Rich Data: The scrupulous transcription of my interview audio files and reading of students' journals and email correspondence to me provided the rich data that I drew from the interviews and focus groups.

Member Checks: I clarified my understanding of what my subjects told me through systematically soliciting feedback from the students concerning the meaning that they drew from their experiences.

Advantages of being an insider: As the Department Manager and Assistant to the Chair, I brought to this study an understanding of the program, the students, the university and the available student services and administrative processes. Thus, I corroborated the students' statements from my own background knowledge. At the same time, I was vigilant not to allow my insider knowledge to bias my interpretation of the students' experiences.

The role of the researcher

As the Department Manager and Assistant to the Chair, I interacted with many of the students in the study as their liaison with faculty and administration, and their supporter and friend. My relationship with these students developed throughout the course of this study, and I am still in close touch with some of the students. Through my data collection and analysis of these students' experiences, I hoped to understand better the challenges and obstacles they faced on the road toward their undergraduate degrees. My findings inform institutional practice for academic departments of computer science, as well as the administrative and academic staff, that support these students.

Limitations of the Study

A limitation of qualitative research is the inability to claim the results can be generalized to or representative of the larger population. However, my goal is not generalizability of the data, but rather to draw data, rich in depth and breadth from my study subjects, which is true to these students' experiences

and which will lead to developing theory to inform institutional practice in how to serve best this population.

CHAPTER TWO

REVIEW OF THE LITERATURE

Science, math and engineering majors have always experienced greater student attrition than other majors, and women are under represented in these majors and drop out in disproportionately higher numbers than men. However, in the past twenty years, all science, math and engineering majors except computer science have made considerable strides in their recruitment and retention of women. A few institutions, such as Carnegie Mellon University, have a distinct School of Computer Science. Smaller institutions, which do not have engineering programs, usually house the computer science major within the School of Arts and Science. However, in most institutions computer science is located within the school of engineering. Although engineering majors continue to have the smallest absolute numbers of women, the percentage of women entering all engineering majors except computer science has steadily increased and women's retention in these majors is now nearly equal to men. However the computer science major has experienced a reversed trend since 1984 when women's participation in the major was at a high of 37 percent. After 1984 computer science began a free fall to 26 percent in 1998 where it has remained (National Science Foundation NSF, 2002).

Seminal research studies by Astin, Pascarella & Terenzini and Tinto serve as a backdrop for this literature review on women's persistence in computer science majors because their works define the characteristics of institutional environments that most impact student persistence. Strenta and his colleagues and Seymour & Hewitt explore specific issues unique to science, mathematics, and engineering pedagogy. Seymour & Hewitt also map the student movement in and out of SME majors, illuminating who leaves and why. No definitive research has yet explained why the computer science major is not attractive to women or why women leave the major in disproportionately high numbers, although research into this phenomenon has increased in the past ten years. Major research conducted by Margolis & Fisher at Carnegie Mellon University (CMU) provides my study with a model which documents inquiry and change in female recruitment and retention undertaken by a peer institution.

Persistence of College Students

The literature on college impact and retention over the last fifteen years is largely in agreement that persistence toward a degree is more about what happens after a student begins college than what happened before (Astin, 1993; Pascarella & Terenzini, 1991; Tinto, 1993). Alexander Astin collected data for his book, *What Matters in College: Four Critical Years Revisited,* from approximately 25,000 students at 309 institutions and faculty from 217 of these schools. By surveying students as they entered college in 1985 as freshmen and then again four years later, Astin focused on the college effects of more than 80 student outcome measures to document how students changed from their freshman to their senior year. Astin controlled for students' varying input characteristics, such as high school preparation, race, gender, and socioeconomic group to determine the college environmental factors responsible for various affective and cognitive outcomes. Astin's findings indicate that popular measures of academic program quality such as expenditures per student, faculty/student ratios, faculty salaries and research productivity had little or no direct effect on student development. Instead, learning, academic performance and retention rates primarily were associated with students' interactions with their peers, with faculty, with involvement in out-of-class activities, and with their leadership roles on campus. Astin's Theory of Student Involvement (1993) explains how and to what degree a student changes in college. The amount of a student's learning is directly proportional to the quantity and quality of that student's involvement in the intellectual and social environment of the college.

In *How College Affects Students: Findings and Insights from Twenty Years of Research,* Ernest Pascarella and Patrick Terenzini (1991) reviewed and synthesized 2,600 studies to identify the net and direct effects of the variables analyzed in each study to document the evidence of student change during college and to determine the change in college students resulting from different institutions and from varying experiences within institutions. Pascarella & Terenzini identified the key determinants of college impact to be the degree of student involvement in the campus community, in academic and nonacademic activities, and with faculty and peers both in and outside of class.

Vincent Tinto's (1987, 1993) analysis of student attrition in *Leaving College: Rethinking the Causes and Cures of Student Attrition* is largely in agreement with Astin (1993) and Pascarella & Terenzini

(1991) in that a student's social and academic experiences in college have the greatest impact on the student's decision to stay in college or drop out. Tinto based his findings on analysis of several large data sets, including the National Longitudinal Survey of the high school class of 1972, the High School and Beyond studies of the high school class of 1980, the American College Testing Program 1992 institutional survey, and the Survey of Retention at Higher Education Institutions. Tinto constructed a longitudinal Model of Institutional Departure in which the student's intentions and commitments are subsequently modified and reformulated on a continuing basis through a longitudinal series of interactions between the student and the structures and members of the formal and informal academic and social systems of the institution. Satisfying and rewarding encounters with these systems lead the student into greater integration into those systems, thereby promoting her retention. Negative interactions and experiences reduce integration and distance the student from the institution, promoting the student's marginality and ultimate withdrawal from the institution. Students' interactions with faculty, both formal and informal, play a central role in students' integration into the life of the institution and are particularly important elements in student persistence. According to Tinto, the absence of sufficient contact with faculty and peers is the single most important predictor of eventual departure, even after controlling for the effects of background, personality and academic performance. Tinto also found an important linkage between learning and persistence that arises from the interplay of involvement and quality of student effort. Involvement with one's peers and with the faculty both inside and outside the classroom is positively related to the quality of student effort. According to Tinto, "The same forces of contact and involvement that influence persistence also appear to shape student learning." (1993, p.69)

Patterns of Persistence in Science, Math, and Engineering

While the research of Astin, Pascarella & Terenzini, and Tinto speak to the student experience in all collegiate majors, defection from science, math and engineering (SME) majors has long been considered normal by many academics and professionals in these disciplines because of a widespread belief that the ability to understand mathematics and science is limited to a relatively small proportion of the population. However, in a four year longitudinal study of 5,320 freshman entering science, math and engineering majors in 1988, highly applicable to my study because it investigated gender effects in four highly selective institutions, Strenta, Elliott, Adair, Matier, and Scott (1994) found that science, math and engineering

attrition comes from a pool of disproportionately able undergraduates, as measured by their math SAT scores, challenging this traditional assumption. No published national data exist which compare the switching and persistence rates in SME majors with those of other majors, and most departments and schools do not keep persistence and attrition records. The University of Pennsylvania, the site of my study, does not maintain these records. To develop this data, Elaine Seymour and Nancy Hewitt conducted a large-scale examination of attrition in SME majors to understand the switching patterns of students in these majors. Seymour & Hewitt's methodology took both a qualitative, ethnographic approach through interviewing 335 SME students in seven institutions, chosen because they represent the types of four-year colleges and universities which contribute most to the national supply of SME graduates. In addition, Seymour & Hewitt compiled patterns of switching, persistence and transfer of majors from unpublished tabulations of the 1987cohort of freshman from survey data of UCLA's Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute (HERI). The key findings of this research include:

1 Men's persistence in SME ranges between 61 percent for highly selective institutions to 39 percent for national samples, compared to the range of 46 percent to 30 percent persistence for women. Computer science persistence is 53 percent for men and 31 percent for women.
2 Engineering is the most stable SME major with persistence at 53 percent, and women persist in engineering at rates comparable to men.
3 Women are bunched in SME majors in biology, chemistry, chemical engineering and bioengineering.
4 The level of transfer into SME majors from all other majors is a meager 6.2 percent.
5 Computer Science provides the most switchers into other SME majors—21 percent.
6 Engineering departments gain 13.1 percent of switchers from computer science.
7 More engineering switchers move into business than from any other SME major—13.9 percent.
8 In computer science, women switchers exceed women entrants by 69.2 percent.
9 A larger proportion of biology majors move into computer science than from any other SME major—10.2 percent.
10 The dominant pattern for all switchers, including SME, is to move into social sciences, humanities and fine arts.

The greatest predictors of persistence and academic achievement in college for all students, are high school grade point average and SAT scores (Astin, 1993; Astin and Sax cf., Davis, Ginorio, Hollinshead, Lazarus, Rayman, and Associates, 1996; Pascarella & Terenzini, 1991; Tinto, 1992;). For engineering majors, ability in mathematics is the best single predictor of academic success (Astin, 1993; Levin and Wyckoff 1988, cf., Seymour & Hewitt, 1997; Strenta et al, 1994). During college, the highest risk of SME switching occurs in the transition from freshman to sophomore year, including those who move into other majors and those who leave college altogether. Although the absolute numbers of men who switch out of SME majors is greater than women, the disproportionate loss of women is greater because fewer women major in SME.

A central question in evaluating the role of gender in SME persistence is whether gender has any effect when entering background characteristics, ability, and performance are controlled. The high school grades of college-bound women and men in science and math courses are the same, and women's overall high school GPA is higher. However, women score lower than men on the SAT Math test, all Advanced Placement science and math tests and on all College Board science and math achievement tests (College Board 1988 cf., Strenta et al, 1994). Strenta et al found that while regular mathematics and science course involvement in high school was about the same for women and men, advanced placement courses in calculus and the physical sciences were taken in disproportionately larger numbers by men, indicating a better preparation for college science, math and engineering college curricula by men. Recent NSF data (2002) suggest this trend has reversed in mathematics and boys and girls are now evenly represented in mathematics courses, including higher-level courses such as precalculus and calculus. Although the female students in Strenta et al's sample, regardless of their initial interest in a major, had substantially lower average SAT Math scores than men, now that girls are equally represented in mathematics classes to boys, girls SAT scores may increase. Strenta et al's evidence that experience and success in high school science and mathematics courses, along with SAT math scores are the most powerful predictors of interest in studying math, science and engineering, while gender is the least powerful predictor, has been corroborated by other research (Ginorio et al, cf., Seymour & Hewitt, 1997; Gurer & Camp, 2001). In Strenta et al's study, the direct effect of gender was significant in women being less likely to express an initial interest in a SME major. A significantly larger proportion of women than men left SME, with only 48 percent of the

study's initial group of women in 1988 remaining in an SME major by 1992, as compared to 66 percent of the men. Engineering is the only exception, where women initially interested in engineering were almost as persistent as men. This has been attributed to the high degree of selectivity in engineering recruiting. Gender was only a significant predictor of women being less likely to persist in mathematics and computer science. Gurer & Camp (2001) found that between 1984 and 1996, only 11 to 15 percent of those who took the AP Computer Science AB exam and 17 to 22 percent of the AP Computer Science A test takers were girls, indicating a lack of preparation in high school to study computer science in competitive academic programs in college. Although there is cause to be hopeful that women's persistence in SME majors will increase, there is no indication that the trend of attrition of women from computer science majors will reverse.

Strenta et al (1994) found that the first two years of science and math grades in college, when taken within the major, are a significant predictor of persistence for all students. Although women and men in Strenta's sample who were not science majors fared similarly in science and math grades in the first two years of college, women SME majors earned slightly lower science and math grades, indicating a poorer prognosis for women's persistence in SME. This result is attributed to the more stringent requirements of the science and math courses when taken within the curriculum of the SME major. Contrary to Strenta et al, Seymour & Hewitt (1997) found the mean GPA reported by switchers was not dramatically lower than non-switchers, and that differences in the academic performance in college are insufficient to predict which students will stay and which will leave SME majors. In addition, these researchers found that women often leave SME majors with grades as high as or higher than men who persist. While Strenta's findings indicate that a lack of preparation in pre-college science and math courses are affecting women's persistence, Seymour & Hewitt's findings suggest socio-cultural reasons for women's lower persistence, as compared to men's in SME majors.

Attrition--The Tip of the Iceberg

The problems in SME majors that are experienced by students who drop out are also experienced by those students who do not persist. Seymour & Hewitt (1997) found that switchers and non-switchers did not differ in performance, attitude, behavior, abilities, motivation and study-related behaviors. Instead, the two groups expressed similar concerns and reservations about the SME majors. What distinguished

those who persisted from those who switched was the development of particular attitudes and coping strategies, and sometimes a serendipitous intervention on the part of faculty when the students may have been at a critical turning point in their academic studies. Seymour & Hewitt use the iceberg metaphor to convey the overarching findings of their research. The issues, which contribute most to the decision to switch from an SME major, are experienced, in some degree, by all SME students. The implication is that there is something terribly wrong with the pedagogical construction of SME disciplines.

Through extensive interviews with SME switchers and non-switchers, Seymour & Hewitt (1997) isolated 23 factors of greatest concern to SME majors. Non-switchers cited an average of 5.4 of these factors as concerns, while switchers cited an average of 8.6. Women and men largely cited the same concerns that were critical to their switching decision. However women and men rated the degree of importance of a factor in their determination to switch differently.

Factors in the switching decision cited more often by women included:

1 Greater concern in making their education, their career goals and their personal priorities fit coherently together, and less willing than men to put career goals above considerations of personal satisfaction
2 Choosing another major which offers greater intrinsic interest, and a better overall educational experience
3 More likely to believe that SME career options and lifestyles are less appealing to them than other options
4 More conceptual difficulties and academic problems, which were serious enough to factor into their switching decision

The strongest difference between men and women was found to lie not in their reasons for leaving SME majors but in their reasons for entering them. Women were more altruistic than men in their career goals and more likely to pursue a major with prospects of humanitarian or personally satisfying work. The higher incidence of women reporting conceptual difficulties and academic problems as a factor in switching than men may be evidence of women experiencing more doubts than men about the adequacy of their abilities.

Factors in the switching decision cited more often by men included:

1 More willing to shift majors as a means to improve their career prospects, and citing the poor expected material return of the SME major on their investment of time, money and effort
2 More likely to weigh the costs against the tangible benefits of their persistence in a major

3 Impacted more strongly than women by the effect of curriculum pace, workload, the high degree of competition and lower than expected grades in SME classes—aspects of the weed-out system

These factors suggest that men may be more acutely aware of their responsibilities after college to earn a living and support a family, and this cultural consciousness impacts both their choice of and persistence in a major. It is noteworthy that, according to Seymour & Hewitt, men more often than women fail to establish peer groups for collective study and academic support. This finding may be the reason for more men than women citing curriculum pace, workload and competition as a prime factor in their switching decision.

Factors in switching decision cited nearly equally by women and men included:

1 Inadequacy in their high school preparation to prepare them for the SME major
2 Criticism of faculty pedagogy in SME majors

The loss of interest in an SME discipline is closely associated with disappointment with faculty as teachers for both women and men. The high proportion of students' citing the inadequacy of their high school preparation to study SME on the college level points to curricular issues, both in high school and college. This factor may be an indication that high schools and college departments must work more closely together to structure curriculum. In addition, the pacing and curricular structure of the college major may also be an issue for these students in that courses may assume more pre-college background knowledge and preparation than students actually have.

The Weed-Out System in SME Majors

Research indicates that students may be deliberately weeded out of SME majors. The National Science Foundation statistics on the depleting SME pipeline show that of the 750,000 high school sophomores in 1977 expressing an interest in science and math, only 78 percent of these still expressed an interest in majoring in SME in their senior year. After their introductory college science course, only 45 percent of them still expressed an interest in pursuing the major, and only 27 percent of the original 750,000 high school students actually earned the bachelor degree in science, math and engineering. From this pool of SME graduates, only 61,000 (8 percent) pursued graduate studies in science and engineering, producing 9,700 Ph.D.s or a scant .24 of one percent of the original pool (NSF Report, 1987, cf., Tobias 1990, 13). Over a half million-college students take an introductory science course each year, yet the defection from SME continues unchecked from this initial experience. The rigidity of introductory science

courses is well documented as palpably competitive, intimidating, designed to weed-out all but the most elite, and impersonal and devoid of any sense of community among students and faculty due to huge classes and the typical SME style of pedagogy (Brainard & Carlin, 1997; Seymour & Hewitt, 1997; Strenta et al, 1994; Tobias, 1990). Inordinately time consuming, students find it difficult to earn a high grade even when a disproportionate amount of time is devoted, compared to other non-SME subjects. Tedious, boring and dull, exacting excessive conformity, learning for the exam rather than to gain any real understanding of how concepts relate, failing to move into a realm beyond the basic cut and dried facts are the common criticisms of courses that introduce students to the SME major.

A widespread, longstanding belief is that the disproportionately higher degree of switching from SME majors as compared to non-SME is because the ability to understand mathematics and science is so intrinsically difficult that it is limited to a small segment of the population. Therefore, large-scale attrition in SME majors is normal, and even appropriate. The traditional "weed-out" system functions to assist in this process. Normally the "weed-out" courses are those taken early in the major, and therefore it is no surprise that most SME attrition occurs in the freshmen and sophomore years. If a student makes it through the SME "boot camp," he becomes a full-fledged member of a very elite club. Evidence suggests that psychologically women fare more poorly in the "weed-out" system than men since women's early socialization stresses consensus and accommodation in contrast to the more competitive and hierarchical male socialization found in SME majors (Brainard & Carlin, 1997; Margolis & Fisher, 2002; Seymour & Hewitt, 1997; Tobias, 1990).

SME Pedagogy

Students most often indict the poor teaching of SME faculty for their lack of success in SME courses. Specifically, students charged that SME faculty do not like to teach, do not value teaching as a professional activity, and lack any incentive to learn to teach effectively. Students cited faculty preoccupation with research and the bias of departmental reward systems as the primary reason for faculty's failure to pay serious attention to teaching undergraduates or pedagogical techniques. However, the same students could cite faculty in non-SME departments who were known for good teaching, indicating a problem with science curriculum and pedagogy in general. Students rated engineering faculty last in comparisons of good teaching (Seymour & Hewitt, 1997; Strenta et al, 1994).

Students often perceive a course to be too “hard” when it is difficult to get a good grade, excessively time-consuming, boring or dull. Introductory courses, especially in engineering, were considered duller than advanced courses, suggesting an impact on retention, since most students switch after the freshman year and after the introductory class in the major. Sources of dissatisfaction include large, impersonal class size which does not permit group work, and which promotes passive learning, precludes discussion and questions, and fosters competition and a lack of community among students. Students charge that science pedagogy in introductory classes emphasizes the memorization of facts absent of context, is deficient in concepts, interpretation, and theory, and emphasizes learning merely to pass the exam rather than to gain long-term contextual understanding. Students also see an inherent unfairness in the lower GPAs of SME students as compared to non-SME majors (Strenta et al, 1994; Tobias, 1990). Moving SME pedagogy from a focus on teaching to a focus on learning, and from selecting for talent to nurturing talent will increase the persistence rate in SME for both women and men (Seymour & Hewitt, 1997, 314).

The Role of Financial Aid in Persistence

Studies differ in their assessment of the role of financial aid on persistence and academic achievement in college. Research asserts that financial aid is an important factor, although there is disagreement on whether financial aid directly impacts educational attainment, or indirectly through intervening variables. Indirect variables include academic factors, a student's socialization process, and such psychological outcomes as satisfaction with the institution, perceptions of fitting in or belonging at an institution, perceived utility of the education from the institution, commitment to the goal of degree completion itself, and intent to persist (Cabrera, Castaneda & Hengstler, 1992).

State and federal governments have been providing a decreasing share of American higher education revenues since the mid-1980s, forcing colleges and universities to raise tuitions to cover budget shortfalls. Annual undergraduate and graduate tuition currently is increasing one to two percent above the rate of inflation, while financial aid awards in the form of grants are decreasing, and loans are increasing. The percentage of college tuition covered by federal financial grants for low-income students decreased from 68 percent in 1986-7 to 42 percent in 1992-3. Meanwhile federal loans for college costs grew rapidly during this period (McPherson & Shapiro, 1997). Research shows that receiving some form of financial aid

facilitates students' social interactions with other undergraduates because it provides students with enough freedom to engage in social activities to become fully integrated into the social realm of the institution (Astin, 1993; Pascarella & Terenzini, 1991). Moreover, adequate financial aid relieves students' anxieties, making it easier to focus on academic activities that enhance their performance. On-campus work-study programs provide students with the additional benefit of heightened exposure to faculty and academic staff, contributing to students' motivation to maintain a high level of academic performance.

SME students find it particularly difficult to work because of the majors' greater demands on their time than other majors. Time devoted to employment comes at the expense of academic study, and students who have to work see themselves at a disadvantage in highly competitive classes. Seymour & Hewitt (1997) found that financial difficulties were a factor in 16.9 percent of all switching decisions. Financing the college education was most difficult for the students in the most selective and prestigious university studied because this institution was also the most expensive. Engineering students reported more financial difficulties than science and math students. The expectation, promoted by most colleges and schools of engineering, that the engineering degree will take only four years, is unrealistic for many students. Students may find themselves ineligible for the financial aid required to complete their programs.

Women's Persistence in Science, Math and Engineering

Mathematical Self-Concept and Self-Esteem

High school students who achieve in advanced mathematics courses generally form the pool of students eligible to study science, math and engineering in college. While in the past girls have lagged behind boys in taking advanced courses in mathematics in high school, this is no longer the case. The achievement gap between males and females in mathematics from eighth grade through high school has narrowed; both male and female high school students have experienced equivalent gains in completing mathematics courses, including algebra II, precalculus and calculus, generating a substantial pool of female students qualified to study quantitative majors such as computer science (NSF, 2002).

Mathematical self-concept is a positive predictor of persistence in quantitative majors Astin and Sax cf., Davis et al, 2001; Brainard & Carlin, 1997; Sax 1994; Seymour & Hewitt, 1997; Strenta et al, 1994). Sax found that women upon college entrance express lower self-ratings of their mathematical

abilities than do men, and this disparity increases during the college years. Declines in math self-concept are more pronounced in selective institutions. Sax postulates that it is aspects of selective environments, such as competitiveness, that bears responsibility for this. Academic self-confidence is determined by both the ability of the student and the ability of the peer group. Selective colleges may be able to reduce the gender gap in math self-confidence by adopting pedagogical styles that encourage women to enroll and persist in quantitative fields, incorporating peer tutoring, mentoring groups, and a more cooperative and interactive curriculum (Seymour & Hewitt; Sax; Tobias, 1990).

Women tend to internalize academic problems, blaming themselves for their lack of ability, while men externalize these issues, more often citing poor teaching or course materials as the culprit for their academic failures (Seymour & Hewitt, 1997; Tobias, 1990). Brainard & Carlin (1997) found that most of the female students entering the University of Washington with intent to major in SME began with a high level of self-confidence in their abilities in math and science. Both of these levels dropped significantly over the course of the first year in college. After the first year self-confidence increased slightly and continued to increase throughout college. However, self-confidence never rebounded to the level experienced as entering freshmen. Studies indicate that overall academic self-concept may be causally linked to academic achievement. Other factors attributed to the increase in self-confidence in college include positive ratings of teaching quality; interest in coursework; participation in a study group; positive influence of technical courses, male friends, faculty, advisors, and mothers; participation in student professional societies; working during the academic year in science; and recognizing career opportunities (Astin, 1993; Brainard & Carlin; Sax, 1994; Seymour & Hewitt;).

The Illinois Valedictorian Project (cf., Widnall 1988, p. 1743), another study which compared the self-confidence of men and women, followed and periodically interviewed 80 students who had graduated at the top of their high school classes in 1981. This group continued their high academic performance in college, with women earning an average final college G.P.A. of 3.6 and men 3.5. Despite their excellent academic results, when questioned about their self-estimate of their intelligence relative to their peers, women reported a shift in self-esteem to lower ratings. Although women's and men's self-esteem were comparable at the beginning of the study, by the senior year in college, no woman from the Illinois Valedictorian Project had a self-esteem in the highest category, while 25 percent of the men did, even

though the G.P.A. of the women was higher than that of the men. In comparison to men, women students reported a higher degree of feelings of powerlessness, and increased pressure and isolation, and perceived the academic environment to be detrimental to their health (cf., Widnall; Pearl, Pollack, Riskin, Thomas, Wolf, & Wu, 1990). Strenta (1994) found science grades in college to be a highly significant negative predictor of depression and confidence, and gender to be a strong independent predictor of depression about SME academic progress and of questioning one's ability in the sciences. Surveys of male and female graduate students preparing for scientific and technical careers at Stanford and M.I.T. indicate that this trend continues through graduate school, and becomes a permanent feature of the working lives of many professional women in science and engineering (MIT EECS Committee on Women Undergraduate Enrollment, 1995; Etzkowitz, 1994). Etzkowitz found that barriers detrimental to women in science and engineering are reinforced by "cumulative disadvantage" factors, including the differential socialization of men and women and women's impaired self-confidence. If these barriers remain high, low self-confidence leads to increased attrition.

Stereotype Threat and Academic Disidentification

Claude Steele (1997) found that women in quantitative majors and African Americans in school suffer similarly by the phenomena of stereotype threat and academic disidentification. According to Steele, to sustain academic success, academic achievement must be a part of one's self-definition or personal identity to which one is self-evaluatively accountable. A student who identifies with an academic domain perceives good prospects for herself in the domain, believes that she has the interests, skills, resources and opportunities to achieve in the domain, believes that she belongs in the domain and that she is accepted and valued, and enjoys sustained achievement motivation. Gender roles and biases in quantitative subjects produce societal pressures, which can frustrate women's identification with the domain of mathematics. When women are negatively stereotyped in mathematics, those women, who are identified with the domain of mathematics, face the further barrier of stereotype threat, the threat that others' judgments or their own actions will negatively stereotype them in the domain. When this threat becomes chronic for a woman who spends considerable time in a competitive, male-oriented, math environment, it can cause disidentification, a reconceptualization of the self and of one's values, in order to remove the domain as a self-identity and a

basis of self-evaluation. This survival mechanism undermines sustained motivation in the domain as it protects the woman's self-image and self-worth.

Studies conducted by the Educational Testing Service (Ramist, Lewis & McCauley-Jenkins, 1994, cf., Steele, 1997) have observed an over prediction or underperformance phenomenon in African Americans and women. Over prediction occurs when students from a group wind up achieving less than a test of preparation, such as the SAT, predict that they will achieve. The ETS studies found that women perform less well than men at comparable SAT levels in technical and quantitative courses such as engineering, physical sciences and computer science, but not in non-technical areas such as English. Underperformance reliably occurred among women who were talented in math and science and who took courses that were intended for majors. However, this underperformance did not occur among women with less math and science preparation, who took courses in these areas intended for nonmajors.

Steele (1997) tested the theory that the biological limits of women's math ability do not emerge until the material tested is difficult, a pattern of evidence that has been used to suggest a genetic limitation in women's math ability. Steele recruited female and male college sophomores, who were both strong math students and strongly identified with the mathematics domain, and gave them a difficult math test. The participants were told either that the test generally showed gender differences, or that it showed no gender differences. As Steele had hypothesized, the women performed worse than the men when they were told that the test produced evidence of gender differences, but they performed equal to the men when the test was represented as insensitive to gender differences, even though the same ability test was used in both situations. Stereotype threat was also found to have a negative impact on women's performance as compared to men's in engineering exams (Bell & Spencer, 2002).

In his classic study of Asian-American students who achieved considerable academic success in quantitative courses, Uri Treisman (1992) identified the successful study patterns typical of these students and successfully replicated them for African American students in his calculus courses. Treisman's work highlighted the key elements of students' success: group study and support, high academic expectations stressing excellence rather than remediation, a shared academic experience, and increasing students' self-confidence.

Lack of a Critical Mass of Women in SME Classes

Research has questioned whether a lack of a critical mass of women in SME classes would cause male students to discriminate against female students in class. Blalock (1967, cf., Sax, 1996) suggested that discrimination toward a minority group would increase as the relative size of the minority group becomes larger. As the percentage of minorities increases in a group, the threat of potential competition to the dominant group increases. In contrast, Kanter's theory of "tokenism" (1977, cf., Sax, 1996) asserted that as a minority group becomes proportionately smaller, members of that group would experience declines in performance, self-esteem, and satisfaction. Sax attributed the lack of consistent findings in research to a methodological limitation through the absence of relevant controls. Sax found that after controlling for students' pre-college characteristics and experiences, the major field, and the college environment, the proportion of women in the major had no effect on men's and women's grades in the major, academic self-concept, mathematical self-concept, social self-concept, satisfaction with the major or women's persistence in the major. While a higher proportion of women in a major did not promote women's retention in Sax's study, it did promote men's persistence in that major. Conversely, Widnall (2000) found that when the percentage of women students rises above 15 percent, the academic performance of the women improves, suggesting a link between acceptance, self-esteem and critical mass. Other researchers have also found that increasing the critical mass of women increases women's persistence in the computer science major (Cohoon, 2002; Margolis & Fisher, 2002; MIT EECS Committee on Undergraduate Women Enrollment, 1995).

The Role of Faculty

There is little evidence that negative experiences with faculty are a factor in women's attrition in SME (Seymour & Hewitt, 1997; Strenta et al, 1994). Rather it is more what faculty fails to do that cause women to consider leaving SME. Women, perhaps because of their "outsiderness," are particularly vulnerable to poor teaching and unhelpful faculty (Margolis & Fisher, 2002). Women in college have an expectation of establishing a personal relationship with faculty. Because many women depend on faculty for reassurance, faculty plays a critical role in women's persistence both as a source of continuous support and in time of crisis. The response of faculty at critical emotional and academic junctures can have a make or break effect on the persistence decision for women. Seymour & Hewitt (1997, 265-273) postulate that

failing to engage faculty into a personal pedagogical relationship is a major contributor to women's decisions to leave SME majors, and persistence initiatives that do not take this into account will not be effective.

Female Faculty Mentors

Women faculty, who mentor female students, positively impact their persistence. Women in departments with no female faculty experience more difficulty in feeling that they belong in that SME department. Women faculty and teaching staff provide women students with a blueprint for their own place within the discipline and in SME careers. The presence of female faculty is critically important to making the participation of women in a discipline appear and feel normal. However, in large SME departments, the presence of a lone female advisor, which is often the case, will not be enough to address the difficulties women students experience because of their minority status (Cohoon, 1999, 2001; Etzkowitz, 1994, 2000; Seymour & Hewitt, 1997). Women Teaching Assistants can nurture undergraduate students, serve as role models and mentors, and help undergraduates to stay grounded and focused. Upper-class female students that mentor their underclass sisters can also provide an effective means of support.

Career Ambitions and Prospects in SME

Women are far more likely than men to switch out of SME majors because they reject the career and/or life-style associated with their original major. At the East Coast public institution study site, Seymour & Hewitt (1997) found only one group, all of whom graduated from private parochial girls' schools, which cited the replacement of career goals with traditional marital goals as their reason for switching out of SME. The dual-career marriage was not an issue for most freshman and sophomore women. However, senior women who were contemplating graduate school or career plans raised this issue. Overall, women, especially those from economically advantaged backgrounds, exhibited more freedom in switching than men. Conversely, women from families in which the pressure to persist was as strong for daughters as sons were less likely to switch.

Both male and female undergraduates expressed considerable concern for their career prospects in SME, especially without a graduate degree. They worried that they would be relegated to low-level work, which is not enjoyable or worthwhile. Internships and co-ops can play a critical role in this regard.

Schools should provide students with ample opportunities to gather concrete information concerning their future career prospects in the discipline (Seymour & Hewitt, 1997).

Women's Persistence in Computer Science

Although fewer female students choose SME majors and experience a higher degree of attrition in these majors than males, the problem is particularly severe in computer science. In comparison to other SME majors, historical percentages of bachelor degrees in computer science awarded to women reveal a disturbing trend that is unique to computer science. The proportion of bachelor degrees awarded to women in all disciplines has increased almost every year for decades to a high of 55.2 percent in 1996. However in computer science, the percentage of bachelor's degrees awarded to women has decreased almost every year since 1984, when women earned 37.1 percent, to 1996, when the percentage of bachelor's degrees awarded to women declined to 27.5 percent. In this same period, the percentage of bachelor's degrees awarded to women in biological/life sciences, engineering, and physical sciences increased by 12.6 percent, 25.8 percent, and 30.4 percent respectively (Camp, Miller & Davies, 2002; NSF, 2000). The total number of degrees awarded in computer science reached a high in 1987, dropped precipitously from 1987 to 1992 and leveled off through 1996 (NSF, 1998). However, computer science degrees awarded to women decreased by 55.1 percent, far outstripping the 35.1 percent decrease in CS degrees awarded to men. Women have buoyed enrollments in every science, mathematics and engineering major except computer science, and this situation is a major contributing factor to the nation's current inability to graduate enough computer science majors to keep pace with the demand for IT workers. Equally worrisome is the data generated by the Computing Research Association Taulbee Survey (Vegso, 2005) that Ph.D. granting departments, in which Penn is included, grant a lower proportion of bachelor's and master's degrees to women than the broader ranger of schools that are surveyed by the NSF. Research points to several causes for the decrease in women's attainment of the bachelor degree in Computer Science.

Computing Experience—Who Studies Computer Science?

The home environment highly influences a woman to develop an interest in computer science, especially when she has no brothers. In their study of computing students at Carnegie Mellon University (CMU), Margolis & Fisher (2002) found that 40 percent of the men and 65 percent of the women came from households in which one or both parents were involved in computing. In addition, 75 percent of the

men in their study fit the profile of someone who was magnetically attracted to computers since childhood, while only 25 percent of the women fit this profile.

Confidence with computers results from success gained through experience with computers. In many high schools, computing programs are virtually "boys' clubs" and many girls feel that they do not belong in the environment. Girls' relationship with computers tends to be application oriented to solve problems, while boys tend to enjoy more hands-on experience through tinkering with computer parts and "fixing" computers. Through creating their own interesting applications, boys gain confidence in their abilities with computers. The contrasting classroom behavior of boys and girls has been well documented (Association of American University Women AAUW, 2000, 1998, 1992, 1991; Sadker & Sadker, 1994). Boys tend to jump into learning situations and demand attention, while girls are more quiet and polite. The boys often monopolize the computing instructor, leaving the girls to figure things out for themselves. In addition, most computer games, children's first experience with computers, are designed for boys, and the gender bias in educational software also has been documented (Margolis & Fisher, 2002; AAUW, 2000).

Many women find the computing culture alienating, insular, isolating and out of balance. They are put off by the singular and obsessive interest in computing of many of their male peers, and they often perceive the cost of success in the major as too high (Margolis & Fisher, 2002; Gurer & Camp, 2001; AAUW, 2000; Spertus, 1991; Frenkel, 1991). The stereotype of the culture of computing holds that computer science people are narrow, obsessive geeks who spend all of their time in front of a computer and lack all semblances of social skills. Margolis & Fisher found that 69 percent of women and 32 percent of men in the major perceive themselves as different from their peers because their lives do not revolve around computers and they have more diverse interests.

Many women enter Computer Science programs with far less experience with computers than men (Margolis & Fisher, 2002). While familiarity with computer terms such as selection, looping, procedures, arrays and pointers does not guarantee success in college computer science programs, students who know the language of computing enter with a degree of confidence. Similarly, most computer science programs do not require prior experience in programming. However, students who have learned programming in high school begin college computer science with a greater comfort level than those who have not. Males without prior experience are somewhat more likely to switch out of computer science, but not to the degree

of women. Secondary schools, as well as computer science departments, need to level the playing field for men and women in the major by ensuring that all students have the requisite skills to be successful in the major.

A Chilly Climate

Women hold a minority status in computing environments and this affects the way they are treated by their peers and superiors. Computer environments, both in academia and industry, are replete with evidence of male predominance. Women are underrepresented in computing classrooms and labs and they cannot escape unwarranted attention. Male CS students report that female CS students are masculine and unattractive, until they drop out, at which time they are once again considered "normal" women. Some girls adopt a "one of the boys" attitude to avoid notice. Others attempt to diminish attacks on their self-esteem by becoming invisible through making their appearance as plain and neutral as possible (Seymour & Hewitt, 1997). Women's isolation stems from lacking female companionship, exhibiting a more reserved communication style that puts many at a disadvantage, being subjected to a locker-room environment, enduring inappropriate language and continuous rude and patronizing behavior, and feeling like they constantly must prove themselves and their right to be there. These elements also are the basis for the chilly climate hypothesis in computer science (AAUW, 2000, 1991; Frenkel, 1991; Gurer & Camp, 2001; Spertus, 1991).

Strenta et al (1994) found no evidence for a chilly climate hypothesis in SME because for those whose grades were the same, persistence was the same. However, the only exceptions to this finding occurred in mathematics and computer science. In analyzing the persistence of men and women who performed equally well in mathematics and computer science, Strenta did detect a significant gender effect in women's persistence, acknowledging a positive indication of the chilly climate hypothesis in computer science. Sometimes slurs and slights may be subtle and not seem like much when taken individually, but taken as a whole, they create an atmosphere, which can have a major negative impact on female students' psyche.

Programs that Work

The School of Computer Science at Carnegie Mellon University (CMU), a top ranked computer science program, found that women were transferring out of computer science at twice the rate of men. The transfer-in of equivalent numbers of women masked attrition because it allowed the school to graduate roughly the same number of women that it brought in. In 1995, with women accounting for only 7 percent of the incoming freshman class, Carnegie Mellon's School of Computer Science took serious steps to recruit and retain women. In 2000, women made up 42 percent of the incoming class (Blum, 2001; Margolis & Fisher, 2002; Frieze, 2002; Frieze and Blum, 2002).

CMU's remarkable success is largely due to a four-year collaboration between Allan Fisher, then Associate Dean for the undergraduate program, and Jane Margolis, a social scientist and expert in gender equity in education. Margolis & Fisher (2002) undertook a research project, which followed CMU students through their undergraduate studies to identify critical periods in students' education, and factors that contributed to or hindered their success. As a result of Margolis & Fisher' research, CMU instituted the following changes to its recruiting practices and curriculum:

1 6 APT Program--Trained 240 AP computer science teachers on C++ programming, incorporating information on how high school teachers could combat the gender gap in computing. The program was so effective that the teachers became partners with CMU by helping CMU recruit their talented high school girls into CMU's computer science majors.

2 Worked with the University's admissions department to broaden the pool of potential students by changing the profile of incoming computer science students to include non-academic qualities, such as leadership and a commitment to community service, in addition to demonstrated academic competence to achieve a gender-balanced program.

From 1995 to 2000, a period of dramatically rising applications to CMU's School of Computer Science and elsewhere, CMU

1 Increased their percentage of women applicants from 11 to 15 percent, in part through the school's relationships with 6 APT teachers and increased the yield of admitted women students from 7 percent of the incoming class to 42 percent. CMU did not sacrifice its academic standards, but did institute merit scholarships for students with demonstrated academic ability, leadership and community service.

2 Instituted curricular changes that provided first year students four ways to enter the curriculum, depending on their level of computing experience.

3 Put senior, experienced and accomplished teachers in the earliest courses of the curriculum.

4 Developed a unit on diversity and gender equity for Teaching Assistant's training.

5 Developed new courses, which contextualized computer science for students with diverse, interdisciplinary problems and projects.

6 Created an organization for undergraduate and graduate women, Women@SCS and hired a director to serve as moderator of the organization. Women@SCS holds weekly meetings, continuously monitors the curriculum to identify trouble spots, provides peer tutoring for the introductory programming courses, sponsors the Big Sister/Little Sister program, which pairs graduate students and seniors with freshman and sophomore computer science majors, and sponsors a variety of social events to combat social isolation and encourage community.

7 Increased the retention of women in the major. No published research demonstrates the increased retention of women at CMU, but Margolis & Fisher (2002) claim that women's persistence is approaching the level of men's in the major.

Other schools have made progress in improving the retention of women undergraduates, although their results are not as dramatic as CMU. MIT's Department of Electrical Engineering and Computer Science (EECS) undertook an extensive self-study in 1995 and, similar to CMU, concluded that EECS should work with the University admissions office to increase the number of women with an interest in EECS to apply to MIT, and that EECS should offer a slower-paced introductory computer science course for students with limited prior experience in computing. Other initiatives at MIT include bunching women students in large multiple-section courses to achieve a critical mass of women in the classroom, increasing students' social opportunities, providing more support to connect students with undergraduate research opportunities, and exposing students to professional women in the field (MIT, 1995).

Dartmouth College achieved notable results in increasing the retention of women in science and engineering. Components of Dartmouth's program include paid first year research internships with one-on-one work with a faculty member who serves as a mentor, a peer mentoring program pairing first year students with experienced students, an electronic mentoring system, which pairs students and professionals via email,

a twice monthly newsletter for students, and a host of extracurricular activities, field trips, industrial site visits, and special colloquia and seminars featuring distinguished women in the field (Muller and Pavone, 1997).

Several other schools, such as the University of Michigan and the University of Wisconsin, have published accounts of initiatives similar to Dartmouth College to encourage the persistence of women in computer science and engineering (Bernstein, 1997). Most initiatives evolved from faculty grants for research of specific persistence issues confronting individual schools from organizations such as the Sloan Foundation, which funded Margolis & Fisher' research at CMU, and the National Science Foundation. Change requires departmental and school leadership to spotlight the representation of women as an important issue, worthy of faculty research, discussion and commitment to promote change.

Summary of the Literature Review

The literature on student persistence in college is largely in agreement that learning, academic performance and retention rates primarily are associated with students' interactions with their peers, with faculty, with involvement in out-of-class activities, and with their leadership roles on campus.

Women join science, mathematics and engineering majors in disproportionately smaller numbers and drop out of these majors in disproportionately larger numbers than their male peers. Attrition in SME majors, including computer science, might be the tip of the iceberg of structural problems in SME curriculum and pedagogy, injurious to both sexes, but to a greater degree to women. Large, impersonal classes which emphasize the memorization of facts at the expense of experiential learning, a competitive culture fostered by the weed-out system, lack of interaction between faculty and students, and among students, curriculum overload, pacing of course material which demands energy and time disproportionate to non-SME majors, and lower grades and GPAs for SME students in comparison to non-SME are the major indictments of SME programs. These factors are also considered to be responsible for the higher rates of attrition in SME majors.

Financing the baccalaureate is particularly a problem for many SME majors, especially in private universities. Because the time demands are so intensive, students find it difficult to work while in school and be successful academically. In addition, many students require more than four years to complete an SME major, compounding financial pressures.

Among SME majors, computer science has the worst track record for attracting and retaining women, and statistics in recent years indicate this situation is worsening. Women's under representation in computer science stems from women's prior socialization, which inhibits women from participation in areas dominated by men, a lack of interest in computing in high school, low self-confidence when competing in mostly male environments, a lack of pre-college preparation in math, science and computer science, and a low math-self concept. All of these factors are highly detrimental to success in computer science in college. Computer science appears to pose a chilly climate for women in many classrooms and workplaces in our nation. Women's lack of pre-college experience in computing intensifies their feelings of inadequacy in the early courses in the major. The lack of a critical mass of women in the computer major at most schools, and a dearth of female faculty and role models also exacerbates the problem.

Faculty is not responsible for women undergraduates' attrition in computer science, but faculty could do more to promote their persistence. Women students' relationships with faculty are critical to their long-term success in the SME major, and faculty can help by serving as mentors to women students, providing opportunities for women to collaborate with them on research projects and giving them needed encouragement.

Programs such as those undertaken by CMU indicate that it is possible for schools to positively affect the persistence of women in computer science. Initiatives that have achieved considerable success include rethinking and revamping admissions policies, committing resources to developing an active organization for women in the major, performing outreach to high school computing teachers to assist recruiting efforts, developing multiple curricular entrances into the major to provide for students with varying degrees of pre-college computing experience, peer mentoring programs, summer bridge programs, undergraduate research and internship opportunities, exposing female students to computer science careers and women professionals, and increasing faculty's involvement and awareness of gender issues.

To date the research provides no definitive solutions for solving the problem of women's disproportionate attrition in undergraduate computer science majors. However, my study contributes to the growing body of knowledge on this problem and provides the faculty and administration of the School of Engineering and Applied Science with useful data and analysis of the issues specific to the Dept. of Computer and Information Science to assist in developing plans and initiatives for change.

CHAPTER THREE

PORTRAITS OF FOURTEEN WOMEN IN THE FIRST YEAR OF THE COMPUTER SCIENCE MAJOR AT THE UNIVERSITY OF PENNSYLVANIA

Summary of the Study Group

Geographically and ethnically diverse, the fourteen women in the study group hailed from five foreign countries, Canada, the Philippines, Mainland China, Malaysia, and Jamaica, and the states of California, Texas, Maryland, Delaware, New Jersey and Pennsylvania. Their pre-college high school experiences varied from attendance at an independent school for girls to diverse public school systems in the U.S. and Asia, to catholic parochial schools in the U.S. and abroad. One thing they all shared, however, was an aptitude for the study of mathematics, which they cultivated and which ultimately led them to the computer science major at the University of Pennsylvania.

Each member of the group was a highly productive high school student with a long list of national and international honor societies, awards, club memberships and service to their credit. Three of the women had a perfect 800 Math SAT score. Among the eight domestic students, there were three valedictorians and two salutatorians, three National Merit Scholars, two AP Scholars, one Benjamin Franklin Scholar, writers, musicians, dancers, athletes, and community and school leaders. The International students had similar accomplishments. For example, the student from Mainland China scored fifteen out of 60,000 junior high school students in the Regional High School entrance exam. The student from the Philippines was named one of the top 70 students in the Philippines in her junior year of high school. One Canadian student won the prestigious Ontario Academic Scholar award and both Canadian students earned the Canadian Millennium Scholarship. Ten women gained admission to other selective universities on par with Penn. Two of the women gained Early Decision acceptance to Penn. All of the students in the study group enrolled in CSE 120, Introduction to Programming Languages and Techniques I, the first required course in the computer science major in fall 2004. Three of the students were sophomores and the remaining eleven were freshmen. All were traditional-age college students.

High School and Family Background

Three students (21.4 percent of the group) had attended all girls' high schools. Two of these students had attended parochial schools for girls, one an independent school for girls. Ten students were educated in public schools: five suburban district schools and five described by the women as alternative or magnet public schools. One student graduated from an International Baccalaureate program. Seven students in the group reported having little or no experience with computer science before their admission to Penn. The remaining seven students had an AP computer science course in high school and/or a computing atmosphere in their home, which contributed to their interest and experience in computer science.

SAT scores – The average SAT scores for the group were 1418, slightly below Penn's class of 2007 average of 1426 and the SEAS' class of 2007 average of 1447. The study group's SAT scores compare to the SEAS class of 2007 scores as follows: verbal (680 study group/697 SEAS) and math (738 study group/750 SEAS).

Family Birth Order – There was no pattern to the birth order of the study group participants. Five of the fourteen students are the oldest children in their families, six are the youngest, two are only children and one is in the middle. Of those with older siblings, four have older sisters and four have older brothers. Of those with younger siblings, four have younger sisters and four have younger brothers. One student is a twin.

Parents' Education – The parents of the study group participants were, for the most part, highly educated. Twelve of the fourteen students' fathers and eleven of the mothers had at least a college degree. Seven students had fathers who were engineers or computer scientists. Four of these also had mothers who were computer scientists or engineers. Two other mothers worked in science. Another mother was a medical doctor. Two fathers and one mother had a Ph.D. and were professors of computer science. Of the remaining seven students, two fathers held a Ph.D. in business and were professors of business, the parents of one student were in the arts, and two families were in business. One student's father was a pastor and her mother was a therapist. The remaining student's mother was a security worker. Only two students had divorced parents.

Financing a Penn Education – For the most part, the study participants' undergraduate educations were well funded by Penn and/or the students' families. Parents entirely funded the education of seven of the study participants. A combination of parental support, grants, loans and part-time work supported two other students. One student was entirely funded through grants, loans and part-time work. Two students were almost entirely funded by scholarships. A third student had a combination of scholarships and support provided by relatives. One student was supported by a foreign government scholarship. Three students reported some distress over financing the education. These were the students that primarily depended on a combination of grants, loans, part-time work and parental support.

The following fourteen portraits seek to highlight individual attributes and characteristics that these students possessed to uncover the sources of their resiliency and strength as they coped with the first-year in a major overwhelmingly dominated by men and made their individual decisions whether to continue to the second course and finally to the second year.

The names of all of the students in this study have been changed to protect the students' privacy and confidentiality.

Lilly Cohen--Taking Advantage of Institutional Support

Lilly Cohen appeared composed and confident about computer science and her place in the major from the start. Lilly applied as an Early Decision candidate to Penn, and was literally shocked when she got in. She had always expected to attend Rutgers University where her father and sister went, but her family couldn't and wouldn't hold her back when she received the opportunity to go to Penn. Lilly's dad was always into computers. An electrical engineer, her dad earned his BS in Physics and Math, and his MS in Electrical Engineering, and worked in Aerospace Engineering. Her mother was employed as a quality control analyst and software specialist, though she didn't like the field. According to Lilly, her job was a good niche for her, but Lilly considered her mom a computer illiterate. Lilly's older sister, who was 20, studied computer engineering and psychology at Rutgers. Her dad had remarried, and her 2 1/2 year old half-sister, Ann, already loved computers. Two-month old Dianna completed the family. Lilly was close to both mom and dad, and she has taken turns living with each of them.

Lilly described her suburban public high school in New Jersey as one of the best in the state. The first day of computer class in high school marked the beginning of Lilly's love affair with computers. Lilly took two AP computer science courses in high school, A and AB, both C++ courses. Yet she did not participate in any computer science clubs in high school. When questioned about this, Lilly reported, "There was a CS club in my high school. It was a pre-Engineering and Robotics Club. The members participated in competitions. There were not many girls in this club, maybe one girl. I didn't think I had enough experience to participate."

Lilly came to Penn in the summer before school started and went through the two-week training program to become an Information Technology Advisor (ITA) in her dorm. An ITA assists other students with their computing needs. Lilly also elected to live in a STWing (Science and Technology Wing) dorm, a living and learning residential community within Penn's College House System in which students share an interest in technology. Both the STWing and ITA organizations appeared to pay off for Lilly, giving her a comfort level with Penn Engineering early on that was not apparent in many of the other study participants. Another plus for Lilly was her boyfriend, Aaron, a Computer Science sophomore and Penn Mentor who Lilly met in August during ITA training. Aaron had an extremely good reputation among the freshmen for being a mentor who responded immediately via Instant Message, day or night, to a call for help from his mentees and Lilly's friendship with Aaron also positively impacted her computer science studies.

Lilly maintained her enthusiasm for computer science throughout the first semester. She stood out among the group because she actually enjoyed the computer science homework, dreaded by most of the other study participants. Lilly said, "They [the homework problems] are a challenge and a puzzle, and I play with them in a repetitive fashion. They give me a chance to be creative." However Lilly was quick to report to me that "the pacing of CSE 120 is so fast, that you would be lost if you did not have prior programming experience. It is very difficult for an introductory course. My friend at NJIT looked at my problems. She said that their level of difficulty was like an intermediate course at NJIT!" Yet Lilly also reported that she chose computer science at Penn because, "Computer Science is my favorite subject and I think I can do it. Computing is my strongest suit." (L. Cohen, personal communication, October 10, 2003)

Liz Hermine--Riding the Roller Coaster of the Freshman Year

A highly capable student, Liz Hermine was used to doing well in school. She entered Penn in the fall with AP credits in World History, US History, Psychology, Physics, Calculus, Literature and Language, and Biology, having earned a 5 in each of these AP examinations. Liz was admitted to Penn under the prestigious Benjamin Franklin Scholar program. She was uncertain from the start of the fall semester about which engineering discipline to study, but she had been influenced by her dad, a NASA mathematician whose job involved computer science and who encouraged her to study computer science at Penn. Liz knew she would enjoy the logic of the discipline, and she was also attracted to the hardware aspects of the major and wanted to learn more. Liz had been accepted to MIT, the University of Chicago, Tufts, and the University of Maryland. She chose Penn because Penn gave her more options. Here she could combine her technical and liberal arts interests. Liz also chose Penn for its diversity and for its campus. A product of the Maryland Prince George County public school system, Liz learned early the value of diversity in school. Liz's parents were financing her education and she was grateful that she did not have to get a job to cover her expenses at Penn.

Socially gregarious and a leader by nature, Liz had managed to find friends and community in computer science, and she helped many of her peers to become involved in this community. Liz was a proponent of the group learning method in computer science. She usually finished her homework on Tuesday nights and stayed longer to help others. That's how she got to know Dan and Anita and many other first year students. Trying to explain concepts to them helped Liz really learn the material. By helping them, she learned better herself, plus learned to teach and be a better tutor. A founding member of the "Tuesday night de facto study group" which met every week all semester at 9 PM in the lab, Liz reported that the study group made her feel plugged into the major. She shared this important source of support with any student that she knew was having difficulty.

Liz was a model CSE 120 student. She prided herself in her work ethic and habits. Liz never missed lectures, and she looked at the computer science homework early—on Thursday, the day after it was assigned. This gave her the opportunity to "think about the homework problems all week and devise

strategies for solving them." Liz also tried to tackle the extra credit questions. In October, Liz reported that she liked the computer science homework because it required solving a set problem and finding the best solution, and she was enjoying the challenge. However as the semester wore on, Liz became increasingly frustrated by the homework, and the amount of time it required. Liz was the most distraught study participant concerning her performance in the first midterm.

By the second semester Liz decided to leave engineering for a major in the college, but she did not know which major she would pursue. She considered Economics, History, and Cognitive Psychology. Later in the semester Liz decided to major in Economics. But what had precipitated her decision to leave the Engineering school when she hadn't even decided on another major? Liz said that when she learned in December that she had earned a B in CSE 120, she promptly registered for the next computer science course, CSE 121. She was prepared to stay with computer science because she was performing adequately and she liked the usefulness of an engineering degree. Liz said that it was the course planning guide worksheets (CPG) that finally changed her mind. She was planning to go with the Bachelor of Arts in Applied Science Computer Science (ASCS) because of the added flexibility to study liberal arts in this program. But when she looked at the course sheets from Arts and Sciences (SAS), she realized that she liked the prescribed courses so much more. In viewing the SEAS CPG, she realized there might be one course in the coming semester that she didn't hate. Conversely with the SAS course list, there may be one course in the semester that she didn't love. Why was she forcing herself to stay in Engineering? She admitted to liking aspects of computer science and she had made many friends in the major too. But was this enough? According to Liz, to be successful in computer science, one had to be passionate about the subject. She believed that many of her male classmates obsessively played with the computer and their code, exclusive of all other activities. Instead, Liz wanted to apply computer science to solve interesting problems. "I don't want to play with the computer, I want to use it," Liz explained. (L. Hermine, personal communication, February 8, 2004) She found the environment of the major too restrictive and, given the diversity of her interests, she did not believe that the major was a good fit for her.

Elena Choi--a Student in Conflict with the Computer Science Major

Thoughtful and soft-spoken, Elena expressed many interests, goals, and concerns for her education at Penn. In October, she expressed an interest in earning a dual degree in Architecture and Computer Science. The oldest of three girls from a family that migrated from Korea to Vancouver, Canada in 1997, Elena's father is a professor of Business Administration and her mother is a housewife who formerly worked in International Relations. Elena had two younger sisters, 8 and 7 years old. Elena's both paternal grandparents were medical doctors and both maternal grandparents were teachers**.** Elena had been admitted to Cornell to study Architecture, and Dartmouth and Duke to Arts and Sciences, but Penn had admitted Elena to study both engineering and architecture, and that had made all of the difference for her.

Elena struggled throughout her freshman year at Penn with conflicted feeling over whether or not computer science was for her. Elena explained, "This love – hate thing for computers started in high school." (E. Choi, personal communication, October 1, 2003) Elena claimed to have a poor high school background in programming, although she was president of the high school computer club. Elena attended a large International Baccalaureate school in Vancouver. A strong student in quantitative and technology courses, all of Elena's extracurricular activities were computer and technology based and she was the first female to join them. Elena took C++ in high school and hated it, even though she earned an A in the course. She decided at that point to give up on computer science, until she was admitted to Penn and opted for Digital Media Design, a major within the Computer and Information Science Department. She loved computer technology, but not computer programming. She was attracted to computer applications, not to the computer in and of itself. Art, graphics and web design were Elena's passions. She chose computer science to enhance an eventual career in architecture. From the start of the fall semester Elena vowed that if architecture and engineering together were too much for her, she would drop out of engineering. Elena was prepared to spend five years including summers to complete the dual degree.

Elena reported that she made a good transition to Penn. She had arrived on campus early in the summer before her freshman year and took Calculus 103 to feel more comfortable in her new environment. In freshman year, she lived in the quad in an all women's floor in the Women in Technology program. She

was the only computer science major on her floor; many of the other women were biomedical science or electrical engineering majors. Even though there were many other engineering students in her residential program, Elena remarked that they all had less homework than she, and that her housemates were amazed at the amount of homework she had in computer science. Elena reported that she studied all of the time, and had little time for socializing. She believed that her results were showing that she did not have the aptitude for computer science, and that everyone was getting it so much faster than she. At the time, she was committed to completing the freshman year CSE courses, but then she would re-evaluate whether this major was for her. Elena's feelings of conflict over her choice of an engineering major did not abate by the second semester. By the spring semester of her freshman year, Elena decided to drop computer science and was considering a major in either mechanical engineering or systems engineering. However she quickly lost interest in systems engineering and dropped her systems course. She planned to check out bioengineering and bimolecular engineering and enroll in the engineering sections of biology and chemistry. However, by fall of her sophomore year, Elena Choi was an undeclared major in the college.

Moira Joyce--Forging Her Own Path to the Major

A self-described bohemian with a penchant for unusual clothing, Moira Joyce is the only child of a college finance professor (father) and a schoolteacher. There are no computer scientists or engineers in Moira's family, and Moira had no prior involvement with computer science before enrolling at Penn. The tech boom in California had not influenced her either. Moira attended a large public high school with 700 students in her graduating class. She had been accepted to several of the schools in the UC system, including Berkeley and Los Angeles. Moira told me that she hung out in Hollywood and at the Southern California beaches, yet she selected Penn because she wanted to attend a traditional eastern university. Moira's family is fully financing her education at Penn.

Moira's high school offered an AP computer science course but, according to Moira, it was poorly taught and her girlfriends advised her against taking it. Moira took nine AP courses in high school, but not computer science. She believed that her position in the major without a background in computer science from high school was tenuous. Yet Moira was tenacious in her desire to pursue computer science, and she mapped out for herself an untraditional path into the major. She successfully completed the first computer

science course in the major, CSE 120, but did not feel her programming skills were well developed enough for her to continue on to CSE 121. So Moira enrolled in a half credit CSE 123 C++ programming course in the spring semester to gain programming experience. Moira attended TA office hours regularly in the spring. She hadn't realized in the fall what a resource this could be. The CSE 123 Instructor, Dianna Xu, told Moira, "We can help you get better at this [programming]." She planned on taking CSE 120 again in fall of her sophomore year and then CSE 121 in spring. Moira believed that with this plan she would gain a firmer grasp on programming and a greater likelihood of success in the major.

Moira differed from many of the other women in the group in that she didn't worry that she was not naturally gifted in computer science. Moira told me, "The students here are like 'if I am not good at this, I don't want to do it.' " (M. Joyce, personal communication, February 20, 2004) Moira didn't feel this way. She could learn to do it. Fiercely independent, Moira's outward confidence hid her insecurities and fears concerning her prospects in the computer science major. Moira really did not know what she wanted when she entered Penn in the fall. She was attracted to Penn because of the interdisciplinary nature of the majors and the opportunity to study in more than one school. From the start, she wanted to combine engineering with a liberal arts major. She had considered a major in psychology but ruled it out because it takes too many years of school to become a psychologist. She investigated communications, theater, philosophy and political science. In engineering Moira first gravitated to the Digital Media Design program in computer science, then to Systems Engineering, and finally to the Computer Science Engineering major.

Moira enjoyed the integration of computers and humans, which appealed to both sides of her personality. She also had her eye on a future career. Computer Science was practical and her other interests weren't. Moira liked the idea of making something (in this case a computer) do something. She also liked the logic of solving problems. Moira said, "I'm searching for things that interest me and have a likely outcome in a career."

Moira is individualistic and initially was not attracted to joining clubs or sororities at Penn. She was slow to make acquaintances with Engineering students, yet as the first semester progressed, she came to rely more and more on classmates and her Penn Mentor for help. She expressed enormous gratitude to her Mentor (Lilly's friend, Aaron) who encouraged her to email him anytime day or night when she experienced difficulties in understanding computer science material. She also joined a sorority in the

spring of freshmen year and she expressed to me surprise at the support and friendship that she found in her new female friends.

Hwa Fan--Dogged Determination in Her Pursuit of the Major

A naturalized American citizen, Hwa Fan was born in China, and moved to England when she was three years old. When Hwa was nine, her family moved to New Jersey for eight years until her dad joined a start-up telecommunications company and her family relocated to California. Hwa's dad received his undergraduate degree in electrical engineering in China, and his Ph.D. in computer science at the University of Cambridge. Hwa's mother used to work for AT&T at a job, which Hwa described as dull. Her mother once had wanted to become a doctor, but she stayed at home now. Hwa had two younger brothers who were 10 and 6. Her 10-year-old brother was a chess expert and an athlete. Hwa completed 10^{th} through 12^{th} grades in a large public high school in California. She was certain that her high school offered no computer science courses and had no computer science or technology clubs either, although there may have been special interest groups for gaming. If there had been computer science activities, Hwa said that she would have become involved. Her high school was in the Telecom Valley near the Napa Valley, and according to Hwa, technology studies were not as popular there among students as in the neighboring Silicon Valley. Hwa described herself as a well-rounded student, strong in math and science, but also a good writer. A leader in high school, Hwa served as the president of her high school's Youth Volunteer Corp.

Hwa had been admitted to Berkeley but she chose Penn because of the Digital Media Design (DMD) program. It was a difficult decision to take Penn over Berkeley, because the latter was less expensive for Hwa's family. Her education was partially funded by a University of Pennsylvania Trustees Scholarship, and she also worked as an Information Technology Advisor (ITA) at the Hamilton College House. Although Hwa admitted that she felt financial pressure, she also told me that other pressures at Penn, such as excelling rather than merely passing, and achieving academic excellence, were just as intense for her. Hwa pushed herself hard and averaged 6.5 courses a semester. "Why so many courses," I asked. "Why not?" was Hwa's reply. "I'll do as much as I can." (H. Fan, personal communication, December 5, 2003) The summer before her freshman year, Hwa took college credits at the University of California,

Santa Rosa and the summer following freshman year Hwa took an intensive computer science course at Berkeley. A high achieving student, Hwa completed the freshmen year on the Dean's List with the highest GPA in the study group and a perfect 4.0 in the spring semester.

Hwa liked the curriculum in SEAS and she appreciated the assistance provided by Amy Calhoun, the Associate Director of the DMD program, who was always available and ready to help students. Hwa was admitted into the prestigious Management and Technology program at Penn, a highly competitive joint program in Engineering and Wharton. Reflective, opinionated and inquisitive, Hwa often commented on the differences in her experiences in these two schools. She felt that a sense of community was lacking in SEAS. According to Hwa, group work, which promotes students' need to know each other and to work together, was at the cornerstone of her academic work in Wharton. She was an advocate of increasing group projects in engineering because she believed that engineering students need to learn to work as part of a team. Hwa also felt strongly that freshmen DMD students should be required to live together in the model of the Wharton Huntsman program. She knew a lot of Huntsman freshmen and they loved living together. Hwa noted that if the School of Engineering was more community oriented, SEAS students could compete with other schools and not compete within. Nonetheless, she applauded the joint degree programs at Penn, which tie schools together, and which, according to Hwa, are unique to Penn.

Anita Salamat--Pursuing Knowledge for Its Own Sake

Anita is a first generation college student, and no one in her family has ever been involved in computer science or engineering. They are business people who built their business from scratch. An International student from the Philippines, Anita's ethnic background is Philippine-Chinese. Anita is the second of four children. Her older sister, although bright, dropped out of college, and she and her husband have prominent roles in the family business. Anita also has a younger brother and sister. Anita was impressed with her older sister who is an extraordinarily talented marketer and customer interface. Anita called herself "the bookish one." She planned to join the family business after college and perhaps graduate school and handle the financial aspects of the business. Anita's parents never pushed her academically. They were just happy that she was in college. Anita qualified for no financial aid, and her family was financing her education at Penn.

Anita had thought about medical school, but she didn't want to study that long. She hoped to combine computer science with business. She entered Penn as a Wharton student and planned to add CSE as a second major, depending on the outcome of her freshman CSE courses. Anita chose Penn because of Wharton and because of the long and prestigious history of computing and the ENIAC in the School of Engineering and Applied Science.

Anita attended an all-girls Catholic high school**,** which is typical in the Philippines**.** The Philippine system of education stresses equality among students and everyone takes the same classes; AP courses are not offered. Anita's high school is considered competitive by Philippine standards, but it did not even offer calculus. However, she is a good math student and was able to waive Math 103. Anita reported that her high school computer science program was poor, and the only thing she learned was keyboarding. She was not impressed by the male computer science teacher who doubled as a substitute in all other subjects throughout the school. Anita was interested in computer science in high school but decided not to pursue the subject then. Participation in clubs was mandatory and scheduled into the school week. Her school had computer science clubs and activities mainly devoted to web design and other basic stuff that Anita still doesn't know how to do. She could have taken an elective course in PC Troubleshooting but she chose Pre-calculus instead because it was a stronger academic course. Anita's only other computer science experience in high school was a three-day computer workshop the summer after high school graduation. Her partner in class was male, and Anita didn't take the course very seriously. Everything the teams were asked to do, she asked her male partner to do for them. She even asked him to prepare for the quiz at the end of the workshop. But this was a summer activity and Anita just didn't take it too seriously.

Anita found computer science interesting because it demands rigorous thinking and she liked the challenge. Anita wanted to embark on the frontier of new knowledge—get the basics down and move on. She felt that grades should not be so important**.** She is an idealist who is interested more in learning. Anita expressed a resolve to me that she carried throughout her freshman year. She would never consult her grades, never ever look at a grade that she had earned in a course. Anita explained, "I always try to do my best. If I earn an A, I may be tempted to slide in my work and if I earn a poor grade, I will just lose my

confidence. It's better for me this way." (A. Salamat, personal communication, February 2, 2004) Anita had hoped to join the M&T program at the end of the freshman year, but she was too shy to ask her computer science professor for a recommendation. She felt that he wouldn't remember her. However, Anita achieved at Penn as a freshman, ending the year on the Dean's List.

Maria Fusco--Simply for the Love of CS

Born and raised in South Philadelphia not far from the University of Pennsylvania, Maria is outgoing and friendly. Both her father and grandfather are electrical engineers. Maria joined the CSE major in her sophomore year. Her parents never pushed her or her younger brother to excel academically, but Maria pushed herself. Extremely close to her family, Maria poignantly recalled her difficult transition to Penn a year before. She missed home so much, even though she lived only blocks away from campus. She vividly remembered the culture shock she experienced when she first became acquainted with Penn students. She didn't understand why her roommates were fearful of Philadelphia. She had lived in the city all of her life. Yet Maria described herself as a naïve freshman that never lived away from home before. She felt left out at first because she knew nothing of designer labels and didn't own expensive things. Maria was in a sorority at Penn and she loved it. The sorority was a great support system for her.

Maria took an untraditional path into the CSE major, and she highly recommends her route for any student without a computer science background from high school. Maria and her friend Naomi spent the freshman year searching out Engineering majors. They first took EAS 101 Introduction to Engineering, a course designed to expose students to various departments in engineering. Maria considered Systems Engineering for a time. However CSE 110, an introductory computer science course for non-majors with Lecturer Dianna Xu in the spring semester, gave Maria a taste for programming and she found that she loved to write code! That clinched it. Maria would major in computer science! Maria took C++ at J. R. Masterman, a respected magnet Philadelphia high school. However, she credited her choice of the CSE major to that first experience with college programming at Penn.

I asked Maria why she chose Penn. **"**The financial aid package," Maria answered immediately, even though all of her other college applications were made to schools less prestigious than Penn. Maria received a generous financial aid package from Penn, yet she still found financing her education stressful.

She needed to earn $2,000 every summer toward her tuition, and she worked in the Computing and Educational Technology Support office (CETS) at Penn during the academic year.

Maria's goal was to become a software developer and she hoped to get a great job after graduation. Maria enthusiastically described to me her love of programming. "My friends tell me that I smile while I write code." Maria wanted to know her professors, and she made a point of introducing herself to them. David Pope was Maria's SEAS advisor when she was Curriculum Deferred, and she described him as her psychologist. When she declared the CSE major, Maria was assigned an advisor in the computer science department but she never made an advising appointment. Maria wanted to select her own advisor and she decided on her CSE 260 professor, Max Mintz. Maria needed a personal relationship with faculty, and she knew of Professor Mintz' reputation for extending himself to his students. Maria was unabashed in her determination to form friendships with her professors. Recognizing that CSE 120 Professor Pereira is a java aficionado, she looked for him in Java City, the coffee shop in Levine Hall's Cyber Café, and struck up a conversation with him whenever possible.

Maria often looked worn out and frazzled when we met throughout the academic year. When I told her at our February '04 meeting how tired she looked, she told me "I should—I was up until 3AM." (M. Fusco, personal communication, February 18, 2004) Maria had underestimated how long it would take to do the CSE 121 homework. This had happened to her last semester and it had all worked out. It would work out again. Maria was heavily involved in her sorority; it was rush season and she had three midterms within a week. Maria was very matter of fact when she stated her opinions. I asked her if she were feeling well. Maria confided that she had not felt well for a long time. She started missing meals last semester and her stomach was a mess. She was trying to eat healthy and get it back to normal. I asked her if she thought it was from stress. She wouldn't admit to that, but instead declared that missing meals messes up your stomach. It had also happened to her friend. I changed my tact. What was she doing with herself lately? Maria became very animated as she told me about all of the activities she was doing for her sorority. "Do you think it is too much?" I asked her. Maria only smiled and with that she said it all. She would never give this up.

Naomi Mathers--Demonstrating the Wisdom that Develops by the Sophomore Year

Naomi had investigated several departments in the School of Engineering before finally deciding on the Computer Science Engineering (CSE) major. A sophomore, Naomi may have been a bit behind the other students in the major in courses, but her perspicacity put her far ahead of her peers. Naomi reported that she was committed to the CSE major but she worried that she was not passionate about computer science, like so many of the other students. Therefore to build flexibility in her academic program, she broadly mapped a course of study for herself, adding a cognitive science minor through the college and a double major in Urban Studies.

There are no computer scientists or engineers in Naomi's family; her father is a pastor and her mother is a therapeutic riding instructor. Naomi's parents relocated to upstate New York near the Canadian border to actualize her mom's long-time dream to practice on her own ranch when Naomi, the younger of two children, left home for Penn. Naomi's brother, older by two years, attended St. John's College in New York but dropped out and joined the National Guard. Naomi chose Penn because it was the best school to which she was admitted. She was also admitted to Franklin and Marshall and Villanova. Financing her Penn education strained Naomi because her financial aid covered a little more than half of her expenses and she needed to make the balance up through loans, her parents' assistance and her 20-hour per week job at the Annenberg box office. Naomi said that her parents did what they could to help her, but she worked more hours per week than any of the other study participants.

Naomi had a strong religious background and her social network was bound up in her church. Her friends shared their faith through regular meetings in the David Rittenhouse Laboratory in the Engineering School, where most of the student congregation is made up of engineering students. Naomi enjoyed other activities through her church, such as the web team and the leadership team. However Naomi admitted that she often felt lonely at Penn because most Penn students party and she doesn't, primarily because she doesn't drink.

Naomi claimed she gained absolutely no background in computer science in high school. "I wasn't even good with computers!" she once exclaimed. The computer science course at her large, suburban high school was not an honors course. The classes were weighted and the non-honors courses dropped top students' GPA. Moreover, non-honors courses were not challenging. Naomi did not think that

computer science was promoted in her high school. She was involved in no computer science club; she just wasn't interested at the time. "In high school, computer science was not on my radar screen," she told me. (N. Mathers, personal communication, October 14, 2003)

When Naomi entered Penn in the fall 2002, she was attracted to the analytic, concrete, hands-on problem-solving aspects of the engineering majors, but she had no idea which department best suited her strengths and interests. Naomi took EAS 101 Introduction to Engineering, a mini sampler of several engineering majors, with Professor David Pope, whom Naomi, like her friend Maria, described as her psychologist in her freshman year because of their lengthy discussions analyzing her engineering interests in their advising meetings. Programming caught her attention for the first time in EAS 101. In spring of her freshman year, Naomi went on to take the first course in Systems Engineering, but it felt too much like a semi-engineering course to her. Naomi entered the CSE major through a non-traditional path, which worked for her, and she encouraged the department to offer this path to others who have little background in programming and are unsure if computer science is for them. In freshman year, Naomi took CSE 110, Introduction to Programming, a computer science course for nonmajors, which is rigorous but not as theoretical as CSE 120. She needed no experience in computing to be successful in CSE 110, and the material was more tangible. Waiting until sophomore year to join the major gave her time to get her natural science requirements out of the way in freshman year. Then in sophomore year Naomi took CSE 120 with CSE 260, The Mathematical Foundations of Computer Science, in the fall. Naomi said, "It was easier to learn this way because CSE 121 [in spring] breezes over induction and proofs, and 260 taught me this. The other freshmen have not had this advantage since they are in 121 and have not had 260." Although Naomi began computer science a year late, the curriculum made more sense to her in this order and she experienced success in her CSE courses. Naomi earned an A- in CSE 120 and an A in CSE 260.

Ting Li--Demonstrating the Value of a Strong Support System

From our first meeting Ting Li came across as calm and comfortable in the CSE major. A tiny young woman, she did not project an enormous confidence, yet neither did she exhibit the same anxieties and doubts of most of the other women in the study group. Ting described her birthplace, Wuhan, the

capital of a province in the central part of China, as a "messy, dirty, old, large city." Ting's father and mother are computer science professors at the Wuhan University of Technology. Ting is their only child. One of her grandfathers was an engineer, and the other a university physics professor.

In addition to several universities in China, the University of Virginia accepted Ting and awarded her a named scholarship. However, she chose Penn because of the Digital Media Design program in computer science, and also because her cousin is a freshman in the Wharton Huntsman Program. His mother is Ting's mother's sister, who migrated with her husband to the US from Mainland China fifteen years ago when her cousin was five years old. Ting's aunt and uncle now reside in Maryland where her aunt works as a computer programmer and her uncle works for the US federal government. When her cousin was in the 8th grade, his mother sent him back to Mainland China to live with Ting's family for a year to learn his own Chinese culture. The two cousins went to school together that year and became very close.

Ting's parents were responsible for paying $10,000 per year for her to attend Penn, less than a quarter of Ting's total costs. The rest of Ting's expenses were made up through a Trustees grant and a scholarship donated by a Chinese alumnus to help a student from Mainland China. Although Ting's financial aid package was generous, it was so difficult for her family to raise their contribution of $10,000 per year that her aunt and uncle in Maryland lent Ting this money.

Ting was concerned about her future. She was torn between her love for the arts and a practical, utilitarian desire to have a stable career and earn a good living. Since her parents were both computer science professors, Ting assumed that she, too, would become a computer science professor. Ting was raised in a home replete with the arts. Her parents collect all types of art, her father plays several musical instruments, her mother sings, and Ting plays the piano. Since her first experience directing a play in high school, Ting's dream had been to become a director. She tried to reconcile that dream with her practical nature through pursuing the Digital Media Design Program.

Although Ting had traveled the farthest in the study group to attend the University of Pennsylvania from her home in Mainland China, she also had the most highly developed support network in the group. Ting's father was instrumental in helping her set up a support system at Penn, even before she left home. Via an email list, he helped her to locate several students bound for Penn from Mainland China

to study for a Ph.D. in computer science. This support system grew for Ting throughout the fall semester. At first there were three Ph.D. students that she met with regularly for lunch. They befriended her and helped her understand the CSE 120 course materials. By March of the spring semester, that number had grown to ten Ph.D. student friends in Ting's social circle. Ting also regularly emailed her high school classmates in China about topics and class projects in computer science. To Ting, the form and substance of this ongoing communication with her friends at home was routine and natural. Although Ting performed academically at about the median of the study group, she always expressed feelings of calm and commitment to the major. Ting's support system was key to her persistence.

Giselle Pie--Taking Up the Cause for Women in Computer Science

Reflective and introspective, the oldest of three children, all identified as gifted, Giselle Pie seemed wise beyond her years. Giselle's parents immigrated to Toronto, Canada from Trinidad, Tobago before she was born. Giselle's dad is a computer engineer. He had hoped that Giselle would take a pre-medicine curriculum at Penn, but Giselle's experience working at the Hospital of the University of Pennsylvania (HUP) Trauma Center convinced her that medicine was not for her. Although she received no formal education beyond high school, Giselle's mother played an important role in Giselle's academic success. A homemaker, Giselle's mother was always available for Giselle and her younger brother and sister, and as Giselle put it, "gave us more than emotional support."

Giselle attended a "decent" public, suburban high school with approximately 1600 students. Giselle's aptitude in mathematics was identified in the primary grades and in high school she was admitted into the competitive Business and Technology program. Although she was modest and unassuming, Giselle's quantitative ability was a source of great pride for her (Giselle earned a perfect 800 in the Math portion of the SAT test). Besides her mother, Giselle credited her love of learning and her academic success to her junior high school teacher, Mrs. Raymond, who Giselle described as "amazing" in her ability to motivate and teach. Giselle completed Algebra 1 in the 7th grade with Mrs. Raymond and went on to excel in national mathematics competitions. She reported that she was almost always the only girl in her high school math classes and activities. It took Giselle three years to build a reputation of competence and

equality to boys in high school. By senior year Giselle was at the top of her class and the boys came to her for help. She also fondly remembered the encouragement she received from her male high school computer science teacher when she was the only girl in his Visual Basic class. Giselle's high school offered no other programming courses and also no AP courses in computer science; Giselle took every computer course that her high school offered.

Besides Penn, Giselle was admitted to several of the top schools in Canada, including the University of Toronto, Queen's University, McMaster University, and the University of Waterloo. Giselle vividly recalled for me Queen's University's Frosh Week, an annual celebration of Engineering. In Canadian Universities, engineering students have enormous pride, and during Frosh Week they dress in wild costumes and run throughout the campus proclaiming their engineering status in the university. Giselle did not feel that this spirit is evident among students in engineering at Penn and she wanted to participate in activities that foster students' pride in engineering.

Giselle's Penn education was nearly fully funded by a Trustees Scholarship and Giselle worked as an Information Technology Assistant (ITA) in her residence hall and as a work-study student on web page design at HUP to pay her personal expenses. ITA training required Giselle to come to Penn two weeks before the rest of the freshman class. Some of the friendships that Giselle made in ITA training were a great source of support for her, helping her cope with feelings of loneliness and isolation throughout the freshman year.

Giselle is philosophical about the early, required courses in the computer science major. These courses serve as a foundation and students need to "get past this stage," even though it takes two years in computer science. Her roommate studied in the college in the pilot curriculum, and by the spring semester she was already past this foundation stage in her own college education. Giselle was totally committed to doing this in hers. Choosing the CSE major was an easy decision for her because she had always liked computing. Friends said that Giselle had a happy look on her face when she programmed. She has fun doing it because it is like a puzzle. In addition, Giselle identified several areas in computer science that suited her interests. She intended on studying both psychology and computer science to learn how humans think and how computers could replicate these processes in machine learning.

Giselle was determined to fully experience college life, and worked hard at balancing her schoolwork with extracurricular activities. She joined the Synchronized Swimming club in which she devoted long hours to practice and attendance at off-campus meets. However, as her freshman year progressed, Giselle confided to me the almost unbearable feelings of isolation that she experienced in the computer science major. Determined to become integrated into the department, she attended the almost all-male Association of Computing Machinery student chapter meetings of the Dining Philosophers and forced conversation with the male students in labs. Yet Giselle continued to feel frustrated by what she saw as her thwarted attempts to become a colleague of her male classmates. Nonetheless, by her sophomore year, Giselle emerged as a leader among her peers. She became heavily involved in the Women in Computer Science organization and she was determined to change the environment of Penn Engineering to make it more hospitable to women.

Sonia Johnson--Breeding a Girl for Success in Computer Science

Sonia attended an independent school for girls in Dallas, Texas. President George W. Bush's twin daughters attended her school. They were in Sonia's sister's class. Sonia recalled meeting President George Herbert Walker Bush on Grandparents Day. Her own grandfather was a Texas oilman and an MIT graduate in engineering. Sonia's sister came out in Dallas as a debutante. Her dad is an architect, educated at Cornell, and her mother an artist. Sonia's sister studied fashion design. "We are an artistic family," Sonia reported. "Studying Digital Media Design makes sense for me."

The Digital Media Design (DMD) program drew Sonia to Penn and she started emailing Amy Calhoun, the Associate Director of the DMD program, in her junior year. Sonia explained, "The DMD web site sold me. DMD blends art with engineering." Sonia visited Penn in her junior year and never looked at another college. She gained admission to Penn under the Early Decision process. Sonia's parents set up a trust fund that supported her undergraduate education.

Sonia was imbued with all the confidence that an independent girl's school can give. She was serious about her studies, but she also acted in plays with a theater group at Penn. She had many opinions and she expressed them as a matter of fact. Sonia told me that computer science is considered unfeminine, and people don't think of it as a different way of thinking and approaching a problem. She thought that the

nerdy image of computer scientists put high school girls off. Sonia had a different experience in an all-girls high school where girls can be themselves and don't need to immerse themselves in a subject to feel they belong in that subject. Sonia had a year of Java in high school but she had to work hard to do well in CSE 120. Sonia knew how to advocate for herself. She felt that the first test was incredibly knit picky, and tenaciously expressed this to Professor Pereira in the class following the midterm when he asked for comments. Sonia also took initiative throughout the freshman year to get the help she needed to be successful. She joined Penn Mentoring because she said, "I need it," and attended three labs per week when only one lab was required. Tuesday afternoons and evenings in the lab were devoted to solving the homework problems that were due on Wednesday. Sonia went to lab every Tuesday afternoon with Hwa, another study participant and DMD student, and a male classmate. They usually worked independently but Sonia found it both comforting and helpful to have others there if you needed to ask questions. Her classmates were objective and could spot the errors in her code. Sonia thought that this helped students' coding style because students could apply the new knowledge of what they learned from others to their coding style. Sonia strongly advocated student participation in study groups and expressed this preference whenever she saw the opportunity.

Ruth Smith--The Good Daughter

With hair that varied from pink to Marilyn Monroe blonde, Ruth Smith had a penchant for dressing in fatigues and rugged boots and worked hard at being an individual. Ruth had been admitted into bioengineering in Penn Engineering, but she switched to the DMD program in the summer before freshman year when she discovered the program's web site. She admitted having trouble connecting with other students at the beginning of the semester until she met a young man in her computer science class that shared her passion for Japanese anime. The two formed a fast friendship based on this mutual interest and shared their interest in anime with many of their classmates.

Ruth's dad is a Mechanical Engineer who worked as a software designer and her mom is a chemist. Both parents have their master's degrees. Ruth's mother lost her job with a major industrial company during the last recession causing financial pressure for the family. Although her mother has

found a new position, Ruth admitted that her choice of a computer science major was heavily influenced by her parents who perceive computer science as a hard skill, which bestows rewards such as lucrative careers on those who pursue it. In the fall of freshman year, Ruth was already talking about earning an MBA at Wharton after graduation. Ruth was also admitted to Johns Hopkins University where her sister was majoring in computer engineering. She chose Penn for the diversity in curricula, the ability to double major, and the excellent reputation of Penn's faculty. Ruth's parents were financing her Penn education.

Ruth started off her freshman year at Penn on a high note. She had taken the AP course in computer science in high school and she knew how to program in C++. A high achieving student from an "excellent" suburban high school in the Northern part of New Jersey, she felt confident and prepared for the curriculum at Penn and she was eager to get started. However, Ruth became increasingly frustrated as the semester wore on. She reported doing better in her homework than on the tests, and did progressively worse in each exam. Her stress level increased throughout the first semester. She was getting little sleep in trying to keep up with the homework assignments, and by the end of the first semester she was convinced that she would be put on academic probation. Early in January of her freshman year, Ruth notified me that she would not be continuing in spring with computer science.

Ruth came in to see me on February 13, 2004. She looked much better than she had in months. Her eyes were bright and shiny, her hair toned down to a golden blonde, her cheeks rosy and her skin pink. It was so noticeable to me because I had run into Ruth several times in the fall between interviews and she always appeared stressed out and looked exhausted, mumbling to me that she had only two hours sleep the night before. Frankly I had been worried about her. Now she settled back in a chair in my office, delicately eating a sandwich that I served her. She declared that she was much happier. "Why did you decide not to take CSE 121 this spring?" I asked her. "Your C grade in the class qualified you to continue in computer science." Ruth explained she had to do something to improve her grades to avoid being put on academic probation at Penn. "I was surprised to be truthful, but I think that CSE just isn't for me. I have found a passion in Japanese and art that I would like to explore." (R. Smith, personal communication, February 13, 2004) Ruth felt confident that she could pull up her grades and be successful at Penn. She had already dropped one spring course—her computer based art course. We quipped that computers were again disposable.

I probed for Ruth's parents' influence on her decision to add and then to drop DMD. Ruth's face lit up and she smiled broadly when she spoke about her dad. He had told her that it was important to do something you love because you'll be good at it, and if you are good at something, people will notice and you will be successful. "I am better off talking to my dad [than mom]," Ruth said. We talked about Ruth's mom who constantly pushed her in everything. She had made varsity tennis in sophomore year of high school because of the pushing. "Mom usually got good results from the pushing, but there comes a time when you want to try things out on your own," she explained. Still, Ruth worried at length about the impact her change of major was having on her mother. She asked me to arrange for someone to talk with her mother about the jobs she could get in her passions, Japanese and Art. I suggested some of the academic advisors in the School of Engineering's Academic Programs Office and in the School of Arts and Science.

I asked Ruth about her interest in Japanese and business. Did she still want to pursue the MBA? She said no, that was also her mom's idea. We talked about what had prompted her initial decision to study engineering. Ruth had enjoyed biology, physics and scientific research in high school, and her parents promoted science and technology for their daughters. Her mom would say, "Ruth, why don't you take another science course?" Sometimes her mom would soften and say, "Don't do something because of your parents, like I did." But the next day she would again push her into practical subjects that would be helpful in finding a good job. Ruth's mom regrets that she, herself, didn't earn a Ph.D. Her mom had not been exposed to much more than science herself.

Ruth had seemed to be a natural for engineering. She attended a medium-size suburban high school in New Jersey, "the best in the state." With a high school GPA of 5.5, Ruth was a high achiever. She excelled in many Physics competitions in high school. At Penn, Ruth made friends in the DMD program. "The program is small and people know they can't get away with being puffy. In the long run, it won't benefit them. This is the power of small groups. DMD is so small that we could all talk. We're all like 'I don't want to really do CS, but I have to get through this horrible mind boggling experience.' " Yet Ruth had not availed herself of any of the support services offered by the department or the school. She did not participate in a Penn mentoring group, did not seek out tutoring services that were available for CSE

120, did not go to TA office hours, and did not even get involved in the student-initiated study group in the lab.

Maggie Marley--Stranger in a Strange Land

Bubbly, fun, quick to laugh and refreshingly open and honest, Maggie Marley was a delight to work with. Maggie was raised by her mother in a single-parent household in Jamaica. Her older brother is a security guard, but Maggie has uncles and cousins who are electrical engineers. The only black woman in the CSE 120 class, Maggie described herself as a "math and science girl, cause I can't do anything else." (M. Marley, personal communication, October 3, 2003) Maggie has a friend, a junior in the MEAM department in SEAS, who urged her to come to Penn. Maggie was admitted to Cornell and NYU but Penn offered her the best financial aid package. Maggie was majoring in biology and she hoped to attend medical school after Penn. She would be the first in her family—first college graduate, first Ivy Leaguer, first doctor. She enrolled in CSE 120 because she hoped to combine technology with medicine. She was interested in computers and she found that she had an aptitude for technical and quantitative courses in the all-girls catholic high school she attended in Jamaica. There she was exposed to algorithms, binary systems and basic programming.

Maggie differed from the other women in the study group in that she did not identify with men because of her technical aptitude. Her best friends were women. She didn't expect to find as many women in CSE 120 as there were. However, at our October meeting, she hadn't met anyone in class yet. The only friend that she made dropped in the second week. Maggie joined the all women's mentoring group because she didn't want to be the only woman in a mentoring group. That would bother her. Maggie said that she was fine with the CSE 120 course material when in class, but found it extremely difficult when alone, especially the homework. She felt that the lectures and labs were in sync and the lab gave students practice in the concepts introduced in lecture. However, she found the homework assignments to be far more difficult.

Maggie was at a disadvantage in CSE 120 because she was not a SEAS student, but from the College. She did not have the benefit of a computer science faculty advisor, she had never participated in SEAS orientation or any other SEAS activities, and she knew no one in her class or in the computer science

major. Maggie and I talked at length about where she could find sources of support for her computer science homework. She was unable to participate in the "Tuesday night de facto study group" that some computer science students had formed in the lab because she had a class during that time. Maggie told me that she didn't study with others as a rule, because she found studying alone more efficient. She also believed one must put time in alone first to be able to contribute to a study group, and she admitted that she does assignments at the last minute, often late at night, and had difficulty following a group's timetable. Maggie was more concerned about her performance in her other courses, especially those in her major, than CSE 120. She did well in the first computer science midterm, but not in those in some of her other courses. She felt that computer science homework was stealing time away from her major courses because it was so time consuming. Maggie was the only woman in the study group that did not complete CSE 120, but dropped the course after the midterm, even though she had earned a solid B in the exam.

Talia Ling--Identifying with the Oppressor

Quick to laugh and crack a joke, full of fun, with a quick wit and a blunt sense of humor, Talia Ling was one of the most enjoyable students to interact with in the study group. An international student from Malaysia, Talia's education was fully funded by the Malaysian Government. The only restriction imposed by the government on this scholarship is that Talia must study engineering or science. If Talia had had her choice, she would have chosen to study business. Talia spoke in the first interview of preparing one and a half years for state exams to qualify for the Malaysian Scholars Program. She said she was an above average student, but not extremely strong. However she considers herself a strong math student. Talia inherited her mathematics ability from her mother, who is Chinese and a Home Economics teacher. Her father is a Malay and works in Human Resources for a bank. Talia's 21-year-old brother studied computer science at the University of Michigan.

Talia was accepted to Brown and the University of Wisconsin, but she chose Penn because she knew that there were only fourteen other government-sponsored Malaysian Scholars studying at Penn. Talia chose not to attend a university with a higher Malaysian population because she would have been obligated to associate exclusively with them. She had more freedom at Penn to get to know many different

people. Talia explained that Malaysian Scholars are usually males because companies prefer to sponsor men. "Companies assume that girls will get married and they won't work for long in their profession," Talia explained. "This is a waste of the company's money. Girls do better in high school, but a smaller percentage of them are selected to be scholars." (T. Ling, personal communication, December 8, 2003) Talia noted the irony in this situation. Even though most women work in Malaysia, there is still a gender/cultural bias favoring men in the Malaysian Scholars Program.

On several occasions Talia expressed doubt over whether a woman was up to the task of mastering computer science. People in the class stereotyped her, she told me, and she didn't blame them. She stereotyped her female CSE 120 classmates too. Talia thought that the males in the class were much smarter in this subject. The students who were most outstanding in class and who did the homework assignments most quickly were all guys. When discussing with a female classmate the option to join the all-women's Penn Mentoring group, Talia reported that her friend said, "I am not going to join an all women's mentoring group. They are all stupid!" Talia thought she would have a better chance of success in the mixed group because the male students had been helpful. In the end, Talia chose not to join any Mentoring group and usually studied alone. However, she admitted that when she needed help, she needed it immediately. She received support from a male, Indian classmate that she met at the international students' orientation. No one liked him because he was so cocky. According to Talia, he was confident, but no better than anyone else. Talia used her gender with this student to her advantage. She pretended to be stupid. She often emailed him questions when she was stuck on the homework.

Extremely social by nature, Talia needed a wide social circle. In February, Talia told me that the second semester in computer science was even harder than the first to connect with peers. People were friendlier in fall because they needed friends. Now that the clicks and social circles were already formed, people had less reason to be friendly. Besides, most of her friends had dropped computer science. Talia admitted that she was experiencing difficulty because she had no one to talk with about her work. No one in her suite was in computer science. Talia often asked a guy, a good student, in the next suite for help. Talia said, "He is very CSish—nerdy and competitive." Talia's schedule didn't fit lab office hours, and she studied very late at night. Talia didn't feel plugged into any community in computer science. She was off by herself and she didn't know why. "They're mostly guys in CS and they seem like friends and

probably they think of girls as people who probably don't know anything. He [male classmate] probably thinks I'm stupid."

We talked at length of possible female social acquaintances from the second semester CSE 121 class that would share Talia's interests. Together we ran down the class list of female students, attempting to identify someone with whom Talia could feel comfortable. I mentioned quiet Anita, and Talia thought she knew her. We settled on Anita as the one Talia would try to become acquainted with. A month later Talia and Anita appeared at my office door. "Thank you for helping me find a new friend. Anita and I are going to room together this summer!"

On several occasions Talia would bring me a small gift or leave me a note. She wanted to express her appreciation to me for meeting with her and talking through her issues. When she returned to Penn for her sophomore year, Talia presented me with a Malaysian caftan. I had visited Malaysia once and Talia was pleased that I recognized the quality of Malaysian fabric. In a note before the winter break, Talia wrote, "It's really nice of you to be so concerned about how we CS girls are doing and all, and I really appreciate it. It has made me feel more comfortable and welcomed in the department. Thanks for being a friend too!"

Progress in Computer Science in the First Year

The individual attributes, personalities, and motivations of the study participants intermingle and coalesce to give us a picture of women who choose to join a major overwhelmingly peopled by men, and the strategies they use to cope. Lilly and Ting show us how communities of support provided by family, friends and the university can help a student through the roughest parts of the first year. Moira, Anita, Hwa and Sonia demonstrate the confidence to persist borne of determination, individualism and strength. Naomi's and Maria's stories highlight the maturity gained by the sophomore year, which contributes to these students' determination to persist. Liz, Ruth and Elena disidentify with the computer science major to save their own view of self. These women who dropped out of the computer science major after the first course were the students who were most concerned about their grades and the time that computer science assignments demanded of them. Maggie, the only woman who did not complete the CSE 120 course, was also concerned that the time commitment of computer science courses would make it impossible for her to

pursue her other academic interests at Penn. Giselle's and Talia's stories are the most poignant because these two students recognized most fully the nature of the challenges that they face in the major, and they suffer because of their awareness and ensuing loneliness and isolation.

Thirteen of the fourteen study participants (92.8 percent) successfully completed the freshman computer science course required for all computer science majors, CSE 120, Introduction to Programming and Techniques 1. Four participants decided to end permanently their association with the computer science department. Maggie, the only student who did not complete CSE 120, had earned a B grade in the midterm but chose to drop the course in order to concentrate her time on her declared major in Biology. She had initially considered taking a computer science minor, but the investment of time required by a computer science course did not fit with her other academic goals. Ruth is pursuing a Japanese major; she had initially intended to major in Digital Media Design (DMD). Elena, another former DMD major, is now an undeclared major in the college, and Liz, formerly a CSE major, is now majoring in Economics in the college. Ten of the fourteen study participants (71.4 percent) were still involved in the computer science program in fall 2004. Nine study participants (64.2 percent) enrolled in and successfully completed CSE 121, Programming Languages and Techniques II, the second required course in the Computer Science majors, in the spring term. Moira stopped out from the recommended major track, and instead took CSE 123 C++ programming in spring '04 in order to build her skills. She audited CSE 120 again in fall '04 and enrolled in CSE 121 in spring '05.

Although this research study followed the journeys of fourteen individual students throughout the first year in the major, the patterns of the students' experiences and their reactions to these experiences within the group provide a thematic context in which to consider the issues. The next chapter will present and analyze the themes that emerged from this study.

CHAPTER FOUR

FIRST YEAR WOMEN'S STORIES IN COMPUTER SCIENCE:

AN EXPOSITION AND EXAMINATION OF THE THEMES OF THIS STUDY

During the second week of classes in fall 2003, Fernando Pereira, Professor and Chair of the Dept. of Computer and Information Science, allowed me to address his class, CSE 120, Introduction to Programming Languages and Techniques I. This was the first computer science class at the University of Pennsylvania to use the Wu and Chen lecture hall in the newly constructed Levine Hall, which houses the Department of Computer and Information Science. Levine Hall is a glazed pavilion, presenting luminous facades to the approach from Penn's Chancellor Walk. Levine Hall's facades are configured in classical architectural proportions using mathematical ratios following "the golden section" of classical Greek architecture. Elegant and dignified, Levine Hall gives notice of the premiere status of computer science in Penn Engineering. The Hall's predominant space, the Wu and Chen 150 seat auditorium, is stark and unadorned save for the formal cherry wood doors and the cherry wood stage which the professor and his podium, housing state of the art computer and projection equipment, occupies at an imposing distance from the students. Addressing the class from this stage, I told the students that I was Professor Pereira's assistant, and that I had a research interest in finding out how the department could help first-year students, especially women, be successful in the computer science majors. I invited all of the women that day to lunch in Levine Hall conference room 315 directly following the class to learn more about my study. Eighteen of the twenty-four first year women came that day to hear more, and fourteen students signed up with me for a study of women's persistence in the first year of the computer science major.

My research suggests that the women in this study group come from encouraging and supportive families. These women have a thorough grounding in mathematics, which prepared them to major in computer science, but many either have an inadequate background in computer science, or at least perceive inadequacies in their background, which prevents them from beginning on an equal footing with their mostly male peers. Many women in this group lack confidence in their ability to be successful in the major, which undermines their persistence. Issues also emanate from their gender-minority status in the

Computer and Information Science Department, causing them to be socially isolated from their peers and further weakening their resolve to persist. Finally, my research suggests that female first year students could benefit from a computer science community characterized by more frequent interaction and collaboration with faculty and peers. Through a thorough exposition and discussion of these themes, this chapter intends to inform schools of education about the issues first year women face in an undergraduate computer science program in a selective university and suggest ways in which institutional practice can best support this population.

This chapter begins with a description of the undergraduate computer science programs offered by the University of Pennsylvania. The themes that I identified in this study are discussed in sections two through ten. Sections two and three speak to the Pre-college characteristics of the study participants, i.e., the support these students derived from their families in choosing the computer science major at Penn and their pre-college, high school preparation for this major. Section four explores the students' motivations and interests, which propelled them to choose the computer science major at Penn. Section five speaks to the issues that cause some women to lose confidence and interest in the computer science major. Section six looks at the way these students relate to their peers and the social isolation that many women in this study group experienced. Section seven investigates the faculty role in first year women's persistence in the major. Section eight discusses the underpinning of a community of interest that the students currently share and which could be further developed and enhanced by the department, the Engineering school, and the University. Section nine examines the changes in the undergraduate computer science major at the University of Pennsylvania since this study. Section ten analyzes the academic results of the women in the study group as compared to the rest of the class and the attrition in both men and women from the first to the second class in the major. Finally, this chapter concludes by looking at the role of the researcher in this study.

1. The Computer Science programs at Penn

> Students enter the computer science major by designating a program of study from the following:
>
> The **BSE Degree** in Computer Science and Engineering (CSE) gives students a rigorous training in computer science and requires a total of 40 course units.

> The **BSE Degree** in Digital Media Design (DMD) provides students with a rigorous background in computer science as well as with foundation course work in fine arts and communications theory. The major requires 40 course units.
>
> The **BAS Degrees** in Applied Science in Computer Science (ASCS), Applied Science in Computer and Cognitive Science (ASCC), and Applied Science in Computational Biology (ASCB) require students to combine knowledge of technology with an understanding of human and social values. They are designed for students who do not plan to work as professional engineers, and want a customized education, which combines the liberal arts and technology in a manner unique to their career goals. BAS degrees require 40 course units.

University of Pennsylvania, Dept. of Computer and Information Science Undergraduate Curriculum Web site, http://www.cis.upenn.edu/ugrad/Acad.shtml Retrieved April 1, 2005.

The following provides a description of the computer science courses offered by the Department of Computer and Information Science at Penn that are referenced in this paper.

CSE 110 Introduction to Computer Programming
http://www.seas.upenn.edu/~cse110/index.shtml Instructor, Jean Griffin

CSE 120 Introduction to Computer Programming and Techniques I
http://www.seas.upenn.edu/~cse120/index.shtml Instructor, Fernando Pereira
http://www.cis.upenn.edu/~pereira/

CSE 130 Introduction to Computer Programming and Techniques I Lab
http://www.seas.upenn.edu/~cse130/index.shtml Instructor, Jean Griffin

CSE 121 Introduction to Computer Programming and Techniques II
http://www.seas.upenn.edu/~cse121/index.shtml Instructor, Val Tannen
http://www.cis.upenn.edu/~val/home.html

CSE 131 Introduction to Computer Programming and Techniques II Lab
http://www.seas.upenn.edu/~cse131/index.shtml Instructor, Jean Griffin

CSE 260 Mathematical Foundations of Computer Science 1
http://www.cis.upenn.edu/~kannan/home.html Instructor, Sampath Kannan

CSE 240 Introduction to Computer Architecture http://www.seas.upenn.edu/~cse240/ Instructors, E. Christopher Lewis http://www.cis.upenn.edu/~eclewis/ and Milo Martin
http://www.cis.upenn.edu/~milom/

CSE 371/372 Digital System Organization and Design http://www.cis.upenn.edu/~amir/cse371/
Instructor, Amir Roth

CSE 380/381 Operating System
http://www.crypto.com/courses/fall04/cse380/ Instructor, Matt Blaze

University of Pennsylvania course home page web sites, Retrieved April 1, 2005.

Entering freshmen in the School of Engineering and Applied Science (SEAS) may either declare a major in one of six departments (the Computer and Information Science Department (CIS) is one of these) or declare themselves as Curriculum Deferred (CD), meaning that they have not yet selected a major, but they have selected SEAS as the school for their major at Penn. CSE 120 and 121, Programming Languages and Techniques I and II, are the first two required courses in the undergraduate computer science majors. The CIS department also offers another introductory programming course, CSE 110 Introduction to Programming, which is intended for non-CIS majors in SEAS. Therefore, CD students who take CSE 120 are usually considering a major in CIS, because they could have taken the less rigorous CSE 110 if they merely had been interested in gaining programming experience but were not considering computer science for their major. In addition to students who enter Penn declaring a computer science major or curriculum deferred status, students from other departments within SEAS, Wharton, the School of Nursing or the School of Arts and Sciences (SAS), and students with undeclared majors who have designated SAS as their primary school may also take CSE 120. It is impossible to know for certain how many students are actually intending to major in computer science.

Five of the women in the study group declared the Computer Science and Engineering major, and four the Digital Media Design major. Four students were Curriculum Deferred in the School of Engineering and Applied Science, that is they had declared membership in SEAS but had not yet committed to a major. One student had declared her major in the Wharton School and intended to study for the dual degree with computer science. The remaining student was in the School of Arts and Sciences (SAS), with a major in biology and considering a minor in computer science. Eleven students in the study group were freshmen and the remaining three were sophomores. All fourteen reported an interest in the computer science program as a possible course of study at Penn.

2. Pre-college Experiences—the Importance of Family Support

Although the students that participated in this study were ordinary college students, as women they constituted less than 20 percent of the first year student body in computer science. This study seeks to understand what characteristics in these students' pre-college background and family circumstances encouraged them to choose to study computer science at Penn. Parental encouragement figured

prominently in many of the students' background and this source of support continued throughout the freshman year at Penn. Only one of the students expressed feelings of pressure from her parents on her choice of an academic course of study. All of the other students reported that the choice of a major was their own and that their parents would support whatever major they chose. Giselle Pie spoke often of her mother, a homemaker, who was always available for Giselle and her younger brother and sister, giving them a high level of emotional support and encouragement for their education. Both of Ting Li's parents are computer science professors in Mainland China and their careful planning for their daughter's transition to studying in the U.S. was largely responsible for Ting's highly successful freshman year. Ting spent vacations with her mother's sister and her family in New Jersey and from day one at Penn joined a community of Chinese computer science graduate students, which her father had located from China, who befriended Ting, met regularly with her and assisted her in navigating the freshmen year at Penn. Talia Ling was encouraged to excel in math and science by her mother to whom she credits for her inherited quantitative aptitude. Naomi Mathers espouses her parents' strong religious beliefs and plans to follow in her Pastor-father's footsteps and use computer science to help people in undeveloped countries. Anita Salamat's parents never pushed her academically, but are overjoyed with her academic accomplishment as the first in the family to attend college. Anita believes she can best move her family's small business forward through gaining an expertise in computer science. Maria Fusco's parents are always on hand to support and encourage her in her academic program. Maria wrote of her parents in her CS journal,

> I may not be the best or the brightest but my parents are still really proud of me and think I'm doing great. I was talking to my mother about my grades and she told me, "You're doing fine. You will never get this time in your life back so you need to enjoy it. You could study all the time like these other kids but you wouldn't have fun and you would lose all this time. In a few years, no one will care what you got on this test. You have the rest of your life to work." I'm definitely having more fun than most CSE majors and yes, I probably do not work as hard as I could and yes, I do just watch TV sometimes and yes, I do go out to parties every weekend. My dad said, "You're doing great. I would be happy if you got a C in college." and my brother described my grades as "glorious." I'm doing fine (M. Fusco, personal communication, April 9, 2004).

Maria's journal entry is indicative of the unconditional support she received from her parents, even when she was struggling in computer science classes. Her family's encouragement was key to her success in the

first year. The majority of the study participants received a great degree of unconditional encouragement and support from their families to pursue their own academic interests at Penn.

Several of the participants stated that their academic and personal interests were typically considered male interests, and this feature began for several of them in their early identification with their fathers' interests. Although several of the participants' mothers were also professionals, and some in computer science, engineering or other science fields, several participants pointedly spoke of their fathers' influence, rather than their mothers,' on their own technical interests. Lilly Cohen's and Ruth Smith's faces shone brightly and eyes lit up when they spoke of their fathers. Lilly Cohen spoke often about her dad, an electrical engineer who works in Aerospace Engineering, and who was always into computers. Ruth Smith excelled in physics in high school and enjoyed a close relationship with her father, an engineer and software designer, who encouraged her to take computer science and in whom she regularly confided. In a personal interview in December 2003, Ruth stated that she chose the computer science major because of her dad's involvement in the field. Hwa Fan's dad holds a Ph.D. in computer science from the University of Cambridge and because of this, the ubiquitous presence of computers in her home planted the seed of interest in computer science in her at an early age. Liz Hermine's father, a NASA mathematician, largely influenced her choice of the computer science major at Penn. Both of Ting Li's parents are computer science professors in China and Ting assumes that she, too, will become a computer science professor. Maria Fusco's dad is an electrical engineer and Giselle Pie's dad a computer engineer. For seven of the fourteen study participants, engineering is considered the "family business" and their father's careers played heavily in their daughters' choice of the computer science major. However even those fathers not involved in computer science or engineering exerted a major influence on other study participants. Moira Joyce finds her professor-dad's two Ph.D. degrees in Ancient Syrian and Biblical Studies and in Finance "amazing." The academic experiences of Elena Choi's father, a professor of Business Administration, largely affected her choice to enroll at Penn. Elena's dad had been accepted into the Ph.D. program at Wharton when she was a baby but he was forced to decline because of family obligations and Elena's admission to Penn holds high emotional value to her family. For most of the study participants, their relationships with their fathers played a major role in their choosing computer science, a major that is not commonly chosen by women.

3. Pre-college Preparation in High School--Adequate Background in Math, Inadequate Background in Computer Science

In addition to family support, a strong academic background in mathematics and science prepared these women to study computer science in college. Some of the students credited middle school and high school teachers for inspiring them to achieve in mathematics and science. Lilly Cohen, Sonia Johnson, Ruth Smith, Giselle Pie and Maria Fusco all suggested that their math and science teachers, who encouraged them to develop their quantitative skills and to take pride in these accomplishments, fostered their confidence in their quantitative, technical and analytical abilities. Giselle Pie spoke of her public school math teacher, Mrs. Raymond, who put her on the accelerated mathematics track in middle school and motivated her to excel. Giselle had the opportunity to attend the Ontario Science Centre School, a special program in her last semester of high school. Sonia Johnson extolled the incredible academic start that she was given by Hockaway, a private, independent K-12 school for girls. Sonia felt well prepared by Hockaway to handle the freshman year courses at Penn. Sonia credits her teacher, Martha Ashley, for encouraging her to compete in mathematics competitions. Ruth Smith thanks her high school Physics teacher for making it possible for her to participate in "Mission Possible," a high school Physics competition in which Ruth placed first in her state in her senior year. Talia Ling attended a one-year Scholars' Program with a math and science curriculum after high school to prepare her for college. According to Liz Hermine, everyone was geared to study science or engineering in college after graduation from her magnet science and technology public high school.

While many of these accounts of excellent pre-college preparation describe a thorough grounding in math and science and not computer science per se, these students entered Penn with a comfort level in their introductory courses and a confidence in their ability to handle new, challenging material, which was based on their previous experiences and successes. However, several of the study participants reported an inadequate exposure to computer science in high school. Inequality in prior experience with computer science often begins in high school, even for high-achieving math and science girls, preventing them from beginning the computer science curriculum in college on an even footing with many of their peers,

especially males. Some of the participants reported that computer science was not available in their high schools. Hwa Fan picked up her computing skills at home with her dad who holds a Ph.D. in computer science. Hwa said that she would have taken computer science but no programming or AP computer science courses were offered in her California public high school. In Naomi Mathers' and Anita Salamat's high schools, computer science was not considered a subject valuable for high achieving students to study. All Anita Salamat could recall learning in her high school computer class was keyboarding. In Anita's Catholic girl's high school, the computer science teacher was a generalist without sufficient expertise to teach computer science on an advanced level. In Naomi's large suburban public high school, the computer science curriculum is relegated to the technical/vocational or business skills track and is not tailored to a pre-college computer science and engineering experience.

Even when AP computer science programming courses were offered in their high schools, some of the study participants chose not to participate in them. Even though she attended a Science and Technology high school, Liz Hermine sidestepped advanced computer science courses. Then when it came time for her senior project, Liz was sorry. The students in the Robotics club did the best senior projects, but Liz *didn't have enough experience* at that point to participate. Moira Joyce asserted that computer clubs and courses in her California public high school were not activities that "a regular girl would be drawn to." Moira Joyce regarded computer science in her high school as a fringe activity with appeal to a very limited interest group comprised primarily of Asian males who where interested in computer gaming. Lilly Cohen reported that she did not participate in her New Jersey public high school's robotics competitions because she did not think she was mechanically inclined and was afraid that she did not know how to build a robot. There was only one girl in the Robotics Club and the boys always talked about how cool the club was. Lilly admitted that at the time she was *too intimidated to join*, but she wishes now that she had. "It would have been a great learning experience," she said. I asked Lilly what her high school could have done to encourage her to participate. Lilly replied, "Make it clear that no experience is necessary." Maria Fusco and Giselle Pie, independently of one another, offer high schools a suggestion that goes a step farther. "Promote computing to everyone." This study suggests that subtle but pervasive peer pressure among high school girls discourages them from pursuing computer science courses and clubs in high school. Sonia Johnson, who attended the independent girls school in Texas, was the only student in

the study group that reported gaining a valuable computer science experience through Robotics camps that she attended in the summers during her high school years.

Is girls' comparative lack of experience from high school with computer science real or a perception that the female students hold of their computing skills in comparison to those of males? Eight of the fourteen study participants, 57.1 percent, had taken a computer science programming course in high school. A student's achievement of a 5 in the AP computer science exam demonstrates a student's thorough background in programming before entering the Penn major. In fall 2003 none of the female students earned a 5 score in the AP computer science exam, while several of the male students had scored a 5 in this exam. The AP exam that the incoming students in fall'03 had taken covered C programming and the CSE 120 course covered Java programming. Therefore, students could not waive CSE 120 based on a 5 in the AP exam, but instead had to pass a placement exam based on the Java programming language. Six male students passed the CSE 120 placement test in Java and waived the introductory course. None of the women students attempted the placement test in fall 2003.

Only two study participants, 14.2 percent, had participated in a computer science club. Of the five students in the study group who did not enroll in the second course in the computer science curriculum in spring '04, only two of these students, Moira and Liz, did not have a high school programming course and Elena was one of the two students that had participated in a computer science club. Yet all of the women in the study group complained that they had an insufficient background in computer science for CSE 120, the first course in the computer science major. A complaint that was often voiced by all of the women in the group was that a substantial proportion of the males in the class had more experience—too much experience to take an introductory class—making it difficult for everyone else in the class by skewing the examination grades, appearing bored when the professor dwelled on an elementary concept, and asking questions that jumped ahead in the course material. Sophomore Naomi Mathers called this male behavior "a freshman guy thing," and noted in her CS journal,

> November 4, 2003
>
> CSE 120 homework 7 is due tomorrow so tonight I went to the lab to work on the extra credit. While I was there I ended up helping four guys finish their homework. I explained linked lists and a bunch of the methods in the homework. I guess not all the guys are better at computer science,

> but I do have more experience than those guys. I guess I just fall in the middle between those with a lot of experience and those with no experience. That's ok with me.
> (N. Mathers, personal communication, November 4, 2003)

In her January 20, 2004 CS journal entry, Naomi detected that perhaps the men in the class really did not know as much as she previously thought.

> A lot of the "know-it-alls" in 120 seem to have disappeared. Maybe at this point there's a level playing field. Maria and I talk to some of the freshman guys who ask us for help on the homework. I think two of them are considering dropping CSE.
> (N. Mathers, personal communication, January 20, 2004)

Unlike many of the other study participants, in these journal entries Naomi shows that she is able to gauge her level of experience with the material more accurately than the other study participants. Perhaps because she was a sophomore and her peers in CSE 120 were predominantly freshmen, Naomi was able to dismiss the male posturing in the class more easily than the other study participants.

Interviews with Jean Griffin, the Lecturer supporting CSE 120 and Professors Max Mintz, and Val Tannen, who teach computer science freshmen and sophomores, corroborated Naomi's conclusion that many male students covered up their insecurity in the introductory computer science course by claiming that they already knew the material being covered, needed to spend only a few minutes on the homework assignments, and asked questions in class ahead of the material that the professor was covering in order to impress him. Other male students in the class did, in fact, have proficiency in the material covered in the introductory CS course. It was virtually impossible to distinguish the male students who did have an exceptional background in computing from the males who were merely feigning expertise based on their behavior inside and outside of the introductory class.

In a workshop for high school teachers in Java programming held at the University of Pennsylvania on June 29 and 30, 2004, the teachers discussed this issue of women's lack of participation in computer science courses and clubs in high schools with Penn faculty and staff. Not one of the 29 teachers who attended the workshop could recall having more than one or two girls at a time in their AP computer science courses. To fully participate in a discipline or a field and gain acceptance by one's peers, one must learn the language of the discipline. Students need to learn to "talk the talk" before they can "walk the

walk" and function effectively in the discipline. The teachers believed that a lack of facility with the terminology of computer science contributed to many female students' perceived inadequacy in the discipline. Several teachers required their students to use correct computer science terminology in describing solutions to homework programming problems. This critical step of becoming comfortable with computer science topics and terminology was missing for some of the study participants.

When novice women are thrown into a classroom situation with more confident males, they may defer to the male students, allowing them to take the lead in accomplishing course tasks and missing the opportunity to gain hands-on experience with the course material, whether it be writing code or programming a robot. Lecturer Jean Griffin witnessed this when she taught the Computer Science segment of Penn's Pre-Freshman program in summer, 2004. Her curriculum included building a Lego Mindstorms robot with the students. Jean made this observation from her experience in working in groups with the rising freshmen:

> We built a racetrack and each robot car had a light sensor and 2 bump sensors and we had an optional race/competition at the end. I couldn't have done it w/out taking the Villanova workshop this summer. Most kids liked it a lot. We had 20 robots for 10 kids.
>
> My observations about groups with the robot work: Groups of 2 (vs. 3) worked best. In groups of 3, often 2 would become disengaged. In groups of 2 men or 2 women, both stayed engaged. In groups of 1 man and 1 woman, both would stay engaged but typically only the man would handle the robot and do the programming, even if the woman was a better programmer.
> (J. Griffin, personal communication, August 2, 2004)

Even when computer science programming courses were offered in their high schools, many of the women in the study group either shied away from them or did not engage as fully as they could have because they reported feeling intimidated that they did not know as much as the overwhelming majority of the male students in the class, and they did not feel comfortable that they fit in with their mostly male peers. When they signed on for the introductory computer science course at Penn, CSE 120, they were told that no previous computer science experience was necessary to be successful in the course. What they found instead was a course populated mostly by males who either actually had or purported that they had a comfort level in programming from previous experience with the subject in high school or through special interests groups in computer gaming or programming in which they had participated prior to their arrival at

Penn. The same intimidation that these high achieving female math students experienced with computer science in high school was repeated in their first experience with computer science at Penn.

4. Why These Women Study Computer Science

While women and men differ in their secondary school background in computer science, they also differ in their motivations to study computer science in college. Men often become engaged in computer science through their fascination with the actual operating of the computer, while women are more attracted to the applications of computer science (AAUW, 2000; Margolis & Fisher, 2002; Seymour & Hewitt, 1997). To become proficient programmers, students must devote an enormous amount of time playing with their code in order to master a new way of thinking and expression. However, since many women are not drawn to computer science through a repetitious play with the computer as many men are, this learning requirement may explain the greater frustration that women experience as compared to men in devoting long nights in the lab to debugging their code.

All of the study participants except Maria hoped to combine computer science with some other discipline. Ting, Sonia, Hwa, Elena and Ruth opted for the Digital Media Design program because of its emphasis on combining computer science with the arts. Giselle, Liz and Moira were drawn to the cognitive science applications of computer science and hoped to combine the computer science major with an Arts and Science major such as cognitive science or psychology. Maggie saw interesting possibilities in the technology of medicine through combining computer science with her pre-med major. Anita elected to double major in computer science and business because she believes this will give her the best academic background to move her family's business forward. Talia, Lilly, and Naomi planned a second major in Arts and Science, although they had not yet decided on which Arts and Science major they would pursue. All thirteen of these women were drawn to Penn because of the facility that the university provides students in selecting a major in Engineering along with a second major in Arts and Science, Fine Arts or Wharton. They saw the opportunity for developing computing skills that, in combination with a second major, would allow them to explore the applications for computing in another discipline. Only Maria opted solely for the computer science major and hoped to find employment as a computer programmer after graduation from Penn. However all of the students expressed the belief that the computer science major would provide

them with more career opportunities than other majors and all expressed the desire to pursue a challenging career after graduation from Penn.

Although the women had little trouble conversing with me in the personal interviews in October 2003 concerning their prior academic experiences, for the most part they looked at me blankly when I asked them what they expected out of the computer science major at Penn. Two who did not persist in the major, Liz Hermine and Elena Choi, were conflicted from the start over their reasons for choosing the computer science major. Liz described herself as a "people person" and she wanted a people-oriented major. She worried that computer science would not play to her social skills and interests. Liz was also drawn to psychology, philosophy, economics and other liberal arts, and she had hoped that the BAS program in Applied Science Computer Science would give her the flexibility to blend her interests in the liberal arts with computer science. Elena declared to me, "I love computer technology for its amazing applications but not computer programming!" (E Choi, personal communication, December 10, 2003) Elena is passionate about studying architecture at Penn. She sees computer science as a valuable tool for this end, but she was emphatic that architecture is her passion and not computer science. Both Liz and Elena dropped out of the computer science major after they completed CSE 120 in December '03, even though each student earned a B in the course. Both women switched to the School of Arts and Sciences, Liz to Economics and Elena to Undeclared status. Because women are socialized to develop an extrinsic sense of identity, to perform for the approval of others and to attach feelings of confidence and self-worth to signs that others are pleased with them, they may arrive at college with less developed intrinsic satisfaction and goals and lack a clear personal view of what they want and expect out of college (Seymour & Hewitt, 1997, Etzkowitz et al, 1994, Tobias, 1991).

Because the first year computer science courses are programming courses, the women who enjoyed programming had a much easier time persisting than those who did not. Maria explained, "I know that I am a good programmer and that I can program better than a lot of my friends in computer science. That's because I love it. I'm not concerned about grades. I love to program. That's why I'm here and as long as I pass and make it through I'm proud of myself." (M. Fusco, personal communication, October 13, 2003) Similar to Maria, Giselle said in a personal interview in October, 2003 that programming came

naturally to her, and that her friends tell that she has a happy look on her face when she programs. She has fun programming because it is like a challenging puzzle to her. However, the main attraction that computer science holds for Giselle is not the sheer fascination for the computer, but the cognitive science aspect of the discipline. She explained in her CS journal,

> Unlike a lot of my peers, I've realized that I really don't want to be a typical computer engineer. I don't want to be the stereotypical person that people seem to think of when you say you're a computer engineer. I don't want to be a professional programmer or work just with the technology that exists today writing new programs or applications. But, with that being said, I still plan to pursue a degree in computer engineering. I see a BSE in computer engineering as a degree that will provide me with a solid background in computing. It will also allow me to have a professional engineering degree that will give me an edge when applying for jobs. However, I really am interested in, and would like to someday work in the field of cognitive science and artificial intelligence, working to develop new applications and technologies in this field. I feel that by getting a dual degree in the College (currently I plan to pursue a BA in psychology) I will be able to have a strong background in both these fields, which will serve as an asset for my later work. I'm really interested in how humans think, and how these processes can be applied to computers for machine learning and decision processes. I'm also interested in perception, especially vision and applying that to robotics. (G. Pie, personal communication, March 12, 2004)

In this journal entry, Giselle explained that while she understands the comparative advantage that a computer science degree will give her in the job market, her primary motivation for studying computer science is to use the power of new computer technologies to push the boundaries of new knowledge in diverse fields, a goal shared by many academic computer scientists. When they began the major, the participants of this study knew little about the computer science field or available career paths within it. The MIT EECS faculty study on undergraduate women in computer science (1995) found the most statistically significant differences between students who persisted and those who dropped out through asking students questions regarding their career plans after graduation. Female students who viewed the computer science major as leading to creative and exciting careers offering good opportunities for women were more likely to persist.

5. Losing Confidence and Losing Interest in Computer Science

The study participants signed on for the computer science major because they perceived that the applications of computer science to diverse fields such as robotics, artificial intelligence, cognitive science, and bioinformatics would offer wide-ranging opportunities for interesting careers and lucrative employment after graduation. However, the first year in the computer science major was a roller coaster ride for many of the study participants. I was often struck by their abiding lack of confidence in their ability to achieve in the computer science major and their fear of what lay ahead of them in their coursework. These students had arrived at Penn in September so fresh faced, confident, and full of excitement about what the freshmen year would bring. By the end of the first semester, four participants reported that they had lost interest in computer science. Although the remaining ten study participants managed to hang in and continue with the major, most also grappled with their interest and commitment. When self-confidence decreases, women are more likely to leave engineering regardless of their academic performance (Goodman et al, 2002).

Some support services provided by the University of Pennsylvania assisted the study participants in their first year in the major; other services, although available, were not effectively advertised to students and therefore students did not take full advantage of their support. Penn employs the metaphor of the Wheel in organizing its support services for students. The WHEEL has been set up to deliver tutorial help round the clock both in-person and on-line by specially trained student advisors in the College Houses where most freshmen reside. Two spokes of the WHEEL offer academic support for computer science courses, CSE 120, 121, and 260. One of these is the Penn Mentoring Program (PMP) operated by the Office of Learning Resources in collaboration with computer science faculty and staff. Penn Mentors are paid, computer science upperclassmen that have excelled in their computer science courses, and they hold weekly, informal meetings with groups of approximately five students in the College House setting to discuss course topics and homework assignments. The PMP encourages students to use one another as resources for learning. The PMP's goal is to help students learn to work efficiently and effectively in groups, and develop and practice collaborative learning skills that they can adapt to other environments. The academic support given by Penn Mentors also helps first year computer science students develop confidence in their ability to master the subject matter. However, the success of the PMP is dependant

upon computer science faculty and staff to organize the mentoring groups each fall for a new group of first year students. In fall 2003, the CIS department worked closely with the Office of Learning Resources in selection of the mentors and in setting up mentoring groups for the CSE 120 class, and strongly encouraged every student to join a Penn Mentoring group.

Penn's Tutoring Center, operated by the Department of Academic Support Programs, is another spoke of the WHEEL that provides first year computer science students with valuable support. Students can request private tutoring for any course within the university for no additional charge beyond their tuition. The Tutoring Center also provides drop-in tutoring on specific evenings throughout the semester in Satellite Tutoring Centers located at each school for courses which have a historical demand for tutoring services, and supports all courses through providing the resources to hold additional review sessions to help prepare students for midterm and final examinations. The Tutoring Center relies on schools and departments to assist them in targeting the courses that need additional tutoring support and in locating the upperclassmen or graduate students able to serve as tutors for specific courses. During the 2003-04 academic year, CIS faculty, staff and students were not aware that tutoring support for CSE 120 and 121 was available in a Satellite Tutoring Center located in the Engineering Library two nights per week throughout the academic year. The communication and coordination between the CIS department and the Department of Academic Support Programs to make computer science students aware of this university resource did not occur until the spring of 2004 when it became obvious that students were struggling to prepare for the CSE 121 examinations. The Computer and Information Science Department staff now works closely with Director Terri White and the Department of Academic Support Programs staff in coordinating tutoring support and prominently displays the Satellite Tutoring Center hours and the courses supported on the CIS department's undergraduate web pages. Faculty and TAs now routinely direct students to these services, which are critical to the success of many first year students.

Lacking previous experience in computer science and the benefits that accrue from fully accessing available university support services, and not feeling comfortable enough to turn to faculty or peers for help, several of the study participants experienced deterioration in their confidence that they could be successful in computer science. Talia was always upfront concerning her fears in the major. "Scary" was the word that Talia often used in conversations with me to describe the computer science major and its

students. I asked Talia what she meant by this term. "You know," she said, "CSish, competitive, nerdy, unfriendly, intimidating, scary." In computer science class, Talia did not know how to organize the available support systems to help her. She studied alone late at night and related only to a few of the young men in the class by assuming a "dumb girl" persona as a pretext to get their help. She was proud of her ability to camouflage herself this way to get the assistance she needed. At the study group meeting on October 29th, 2004, Talia expressed concern over whether she was up to the task of mastering computer science. Her opening statement elicited a flood of empathetic comments from the other members of the group.

> Talia—CSE is like driving into walls and I'm really stressed out.
> Lilly: CSE is the hardest major at any school and I was warned about it. And it gets harder. I know someone who did well in 120 and 121. He didn't even have to go to class and he is struggling in 240 and dreading 381.
> Sonia: DMD is worth it though.
> Talia: Maybe I'm not suited. I'm not good at it.
> Lilly: Some people are just doing 120 for an easy A and they screw up the class.
> Talia: When we have discussions and everyone goes on and on and you think, what the heck, am I the only stupid one here?
> Moira: I had a horrible experience the first day of class. I came into the class ten minutes late. It was raining and I was soaked. Everyone was introducing himself or herself. They were all saying, like I've been programming for three years and then it was my turn and I said, "like, I'm from LA and this is my first course."
> Talia—Maybe I'm not stupid, but comparatively stupid compared to the people in the class.
> Lilly: When you get into the harder stuff, you could have the comparative advantage. From what I've heard, the upper level classes are completely different.
> Talia: I don't want to ask too many questions because I don't want people to think "dumb girl."
> RP: Professor Pereira sets aside office hours twice a week for questions and hardly anyone goes to see him.
> Elena: I go to my TA office hours with questions.
> Talia: You are too self-conscious to go to the professor.
> Moira: I can be the same way and I know when I'm being too hard on myself.
> (participant group meeting, personal communication, October 21, 2003)

The participant group meeting functioned as a support group for the students. Most of them did not know each other prior to the meeting, but through their computer science course they shared a

commonality and they immediately responded to each other's need for encouragement. Throughout the academic year I was often surprised at how few of the first year computer science students knew one another. They appeared to keep themselves at arm's length from each other to hide what they perceived that they did not know in relation to their classmates.

The perception that their male peers know far more about computer science than they do developed as these female students were subjected to student rhetoric in their class of how easy the computer science assignments were, measured the time it took them to do an assignment compared to others, and compared their performance in homework assignments and exams to the mean of the class. Maria provides an apt description of this observation in her CS journal:

> October 12, 2003
> The night before the test, I studied with the two of my friends. They obviously knew the material a lot better than I did and I was so discouraged not only by their knowledge but by studying from an old test where the student got a12/100 that I considered not even showing up the next day. My friends did end up doing significantly better than I did but I'm glad I took the test and I'm sure glad I studied. I hate being compared to other people and I don't want to know what they got because I don't care. If they're happy, good for them. I just hate when people come running up to me asking me how I did because I don't want to tell them my score and I don't want them to tell me theirs. I feel embarrassed to be happy about my score, which is ridiculous. If I told them I was thrilled about a score below the mean, I don't know what they would think. That's why I just keep it to myself.
> (M. Fusco, personal communication, October 12, 2003)

In this journal entry, Maria struggles with maintaining her self-esteem and self-confidence by not comparing herself to her classmates and not giving them the requisite data to compare themselves to her. Maria's determination, her love of computer programming, her dreams of her future career in the computer industry, and the unconditional support of her family played a large part in seeing her through the rough times in the major.

Lilly also grapples with whether or not she has what it takes to be successful in computer science in her CS journal:

> 11-15-03
> Once again, I managed to come out of the CSE exam completely confident, thinking I aced it, but managed (once again) to get an 83. I'm kind of curious as to what I could have done wrong

> because I don't remember anything troubling. I know that my score is high, but I still get frustrated by things like this because it tells me that I can't trust my feelings as to how well I'm doing and hence never can tell where I stand. HW stats have long been posted and the HW grades are higher than I thought they'd be (at least based on out last [group] dinner discussion). I'm curious to see where I stand overall because *my confidence has dropped*. The grade aspect itself doesn't bother me. It's just that I'm exploring the possibilities of double majoring with other subjects and first want to make sure that I'm in the right place and that CSE is truly for me. Maybe I'm just putting way to much thought into this …or maybe the only reason I'm beginning to question myself is because my sister, very good with computers and far better than me, dropped computer science and is now doing something with computer information systems, or something like that. Also, my friend Vlad has always been incredibly good with computers and knows countless programming languages (as well as many other things associated with CSE) and yet he also stepped away from computer science. Maybe it is the job market (or lack thereof) or maybe it's just their personalities, I don't know. Then again, it shouldn't matter how much more then me they know; I'm at an amazing university and I'm here to learn . . . and learning is supposed to be the most important part. I just have to stop worrying/ thinking about everyone else and start focusing on myself and what I want. Hopefully Penn will get me to where I want to go, and hopefully I won't scare myself into not making the steps to allow that to happen…. I love CSE (for now), and I hopefully will continue to do so. I can't make decisions based on what I think could happen (me start hating CSE or become overwhelmed by it) or that's that, I'm definitely going ahead with it . . . and now all I have to do is hope for the best and work my ass off to help get it. *wishes herself luck* [Asterisks Lilly's; Italics mine]
>
> (L. Cohen, personal communication, November 15, 2003)

In this passage, Lilly struggles to maintain her determination by evoking her "faith in the system," which she hopes will see her through. In our first personal interview, Lilly told me that she chose the computer science major because "computing is my strongest suit." Although this self-assessment makes her vulnerable to negative feedback concerning her performance, it also functions as a major motivating factor for her to persist.

Moira displayed particularly distracting behavior in our second personal interview on December 7, 2003, unconsciously picking at her arms, her hair and her clothing. I attributed her actions to her high level of anxiety as the end of the semester approached. In January, although Moira had earned a C+ in CSE 120, she chose not to enroll in the second semester required CSE 121 course because she believed that she needed more programming experience before she could be successful in the next course. Instead she

planned on retaking CSE 120 in fall'04 and continuing on to CSE 121 the following spring. Moira had had no prior exposure to computer science in high school and she did not assess correctly the time she would need to devote to her programming assignments to stay on track in CSE 120. Moira held herself back from making friends in the major and taking advantage of the available support early on in the semester. By mid-semester she panicked and joined Penn Mentoring, relying heavily on her mentor who fielded Moira's questions 24/7 via the electronic Instant Message. When we met in February, Moira seemed much better than she had at the end of the previous semester. When she returned from the winter break, Moira joined a sorority, something this self-described California Bohemian had never pictured she would do in September, and she was surprised that she was enjoying the company of her newfound "girlfriends." Moira took a .5 credit unit C++ programming course in spring and she worked diligently to build her skills. In fall'04 she was back in CSE 120, determined to succeed in the CSE major.

Students such as Lilly, Maria and Giselle, who believed that they could learn and actually liked programming, seemed to have an internal reservoir of strength, which supported them throughout the first semester. Moira, whose first attempt at computer programming was in CSE 120 at Penn, did not dwell on whether she was naturally gifted in computer science. Moira put it this way, "The students here are like 'if I am not good at this, I don't want to do it.' I don't feel this way. I know that I can learn to do it." (M. Joyce, personal communication, February 12, 2004)

Maggie, Elena, Liz, and Ruth were not as tenacious in their pursuit of success in the major. Maggie was the first to abandon computer science in mid-semester. Maggie had a natural aptitude for programming, but she did not invest the time to ascertain if computer science was for her. She never connected with any person in the major, did not feel comfortable in the environment and decided early on that she could not commit the time required to be successful. By the end of the first semester, Elena, Liz and Ruth made the decision not to persist with the major. These women worried that they did not feel passionate about computer science and were not as "gung ho" about computer programming as their peers. Their fears may have been fueled by the atmosphere created by that which CMU researchers Margolis & Fisher (2002) dubbed "the mythology of the geek culture," a masculine, hacker mentality that pervades the major. Many women in the major feel out of step because they do not share the same intensity for computers as many of their male peers. A female student who was not part of the study group and who

completed CSE 120 with the highest grade among the women and 5th overall in the class did not persist to the spring semester. When I asked her why she replied that the CSE major causes its students to have an unhealthy lifestyle because they must spend all of their time in front of a computer and have little time for fresh air and exercise. Elena also refers to this image of the major in her computer science journal,

> January 18, 2004
> Whenever I go to the computer lab in the Quad, I see Jean and other DMD people working on CSE. I can always count on Jean to be there agonizing over CSE at 3am in the morning. She lives there, works there, eats there and sleeps there. CSE people just seem like the most sleep deprived, overworked, and unhealthy people on campus. And, they just don't seem happy whatsoever. They *do* have pride as CSE students, but they hide it. They know that they are overworked and under appreciated by their peers in SEAS, and to an extent, they see their own selves as geeks. [Italics Elena's] (E. Choi, personal communication, January 18, 2004)

Elena expressed doubts about her ability to hold her own and keep up with her peers in the major. Elena describes the process of losing her confidence when comparing her efforts to her classmates in her CS journal, and she alludes to developing a sense of helplessness. Elena was one of the most prepared women to study computer science, having taken an AP course in computer science in high school and also having been the president of her high school's Robotics club. Yet her perception in the following journal entry is that the CSE 120 class is not an even playing field and she is unprepared to compete with her peers.

> January 18, 2004
> I remember, for the weekly homework problems we had to do in CSE 120, it was often very mind-boggling and frustrating because I felt like I should somehow be explaining on my own to acquire some of the advanced knowledge programming techniques some people in the class already had. My friends and I would spend hours and hours doing a problem only to find out, after submitting the problem, that someone had spent merely 30 minutes on the same problem not because he was genius or particularly smart (I define being smart as being able to go further and faster than anybody with whom you have started out on the same foot) but because he, with his 3-4 years of experience, already knew some tricks on the lessons that were to be covered later in the course. There really is nothing more frustrating than this, because you never know what you don't know. Maybe it's because it was an introductory class, and thus everybody was at different levels, but still, *you really begin to develop learned-helplessness and just sort of give up.* [Italics mine]
> (E. Choi, personal communication, January 18, 2004)

In “Toward a New Psychology of Women,” (1986) Jean Baker Miller analyzed women’s feelings of weakness, vulnerability, and helplessness, which she ascribed to women’s perception, borne of a lifelong conditioning, of an almost magical ability, which men have and women do not. Miller sees this as growing out of a culture in which the female is the embodiment of weakness, while the male is the embodiment of strength. According to Miller, how a person is made to feel vulnerable and helpless and what she then tries to do about it is the most perplexing issue underlying modern psychiatry. In its most extreme form, this vulnerability is akin to psychic annihilation, the most terrifying threat a person can experience and one to be avoided at all costs.

As the first semester progressed, Elena became discouraged because she believed that her results were showing that she did not have the aptitude for CS, and that everyone was getting it so much faster than she. She expected As in her major and she found herself struggling for Bs. Elena’s opening remark in our first personal interview in the fall of 2003 was, “The mean of the class in the midterm was 79. I had studied hard but scored below the mean. You needed to know the material cold. I won’t stay with computer science if I can’t excel in the major.” (E. Choi, personal communication, October 13, 2003) Elena admitted that she studied all of the time, and left little time for socializing. Although Elena earned a B+ in CSE 120, she dropped the DMD major at the end of the semester and experimented in spring ’04 with systems engineering and bioengineering. By fall of her sophomore year, Elena dropped out of engineering altogether for undeclared status in the college.

Like Elena, Liz Hermine also expected to do well in computer science, but she often felt that she was out of step with the other students in her class. Liz told me that going into an engineering major was “like going on automatic pilot” for her coming from a science and technology magnet high school. “All the smart people took science and math classes. I was good at science and math so I figured that's what I would take in college.” Liz protested in personal interviews with me in November ‘03 and February ‘04, and in the October ’03 group meeting that it was not that she was *not able* to do computer science, but she was not sure that she *wanted* to do it. Liz sees the major populated by computer-obsessed students who choose to spend all of their time playing with the computer at the expense of developing more important interpersonal skills. Liz put it this way at the October study group meeting. “It’s not just that the guys have taken classes before. I know guys who have Linux on their computers because they figured out how to use it.

They didn't take a class on it or anything, but they play with it constantly. They like that sort of thing. The easiest way to learn CS is to actually do it. You start to think you are not the type because you are not playing with Linux constantly. I'm not particularly interested in playing with it all the time. I like to be able to use it."

Liz grappled with her choice of the major in several of her computer science journal entries.

> 10/01/03
>
> So I just got the results of my midterm back. Not good. I got a 68 which is way below average, and I definitely do not think is a good indication of my knowledge of the subject. …I am now a little worried about my grade but I am not at all concerned about my ability to grasp the material.
>
> 12/11/03
>
> CSE 120 is over, my final grade in the class was an 83 which I'm not sure what that is in terms of a letter grade. At least a B, which is acceptable. I did decide to sign up for CSE 121 although I've been looking a lot at classes and requirements and things and I'm still not sure I want to MAJOR in CSE, but it's not because I think I CAN'T do it. [Caps Liz's]
>
> 2/02/03
>
> While it's true I was pretty "good" at computer science (I had lunch today with a guy from my class who I used to help who said, jokingly of course, that I have no "excuse" for switching), it really didn't excite me and I didn't really LIKE it that much. I can't see myself being passionate about it. Of course some people say it doesn't matter if your passionate about it as long as you don't dislike it and it makes good money. There is some truth in that, however I find that I am truly passionate about other subjects, and I am not willing to give up my passion for them to pursue something I don't have a particular interest in. SO basically I'm doing what I want to be doing. I actually feel like I was kind of pressured into the whole engineering/science track, basically I was doing it because it's what I thought I <u>should</u> want to do and not because it was what I <u>actually</u> want to do.
>
> [Underlines and caps Liz's]
>
> (L. Hermine, personal communication)

Liz and I corresponded via email throughout the winter break about her decision to leave computer science for a major in economics. Her numerous protestations that she could do it if she wanted to do it may have indicated that she was protesting too much. Perhaps for this high achieving Benjamin Franklin Scholar

who came to Penn with nine AP credits, a B+ in CSE 120 was just not good enough to keep her in the major. Or perhaps at Penn, as she asserts, Liz had the opportunity to explore what she really liked doing and thinking about for the first time.

Like Liz, Ruth Smith was also a high achiever in high school. I bumped into Ruth Smith several times in the first semester in the Levine hallways and in CSE 120 class. She often appeared frazzled and out of sorts, muttering about getting too little sleep. It was difficult to schedule interviews with Ruth because she told me that she was so tightly scheduled with classes, labs and a drawing studio. Ruth was in the Digital Media Design program, an interdisciplinary major in computer graphics, animation, and the design of virtual environments. The DMD program combines a major in computer science with communications and fine arts and requires an intensive course load. On December 5, 2003, Ruth arrived late for her second interview with me. She nearly collapsed in my office, soaked to the bone from a driving rain outside. I immediately helped her out of her wet coat and offered her a cup of tea. Ruth declined the tea, but settled down in a chair in my office and told me about the difficulties she was experiencing in her first semester at college.

> Ruth: I just took my calculus midterm. I'm getting about 3 hours sleep a night. Drawing [studio] takes 9 to 12 hours a week. I have been going to Tuesday nights in the dance lab [CSE 120 lab]. The last homework wasn't so bad because I worked with Sonia. It took me 10 hours….I really enjoy Japanese and would like to minor in it. I'm doing really well in it. It's my little ray of sunshine on many otherwise bleak days. CSE, sometimes I know it, I realize it later. There is no one to tell you [that] you are right on this code. You don't know if the way you are doing it will result in the right answer. Otherwise you could be spending 5 hours doing it the wrong way. I go to the labs on Tuesday nights for help with homework. On Tuesday nights there are 2 TAs in the lab.
>
> RP: How many hours per week do you spend socializing?
>
> Ruth: I'd say none. I only talk to people over email about homework and then I walk to dinner with Sonia. If it weren't for my friend, she has been explaining calculus to me, I would have left. It's just that you work so hard, you work harder than you ever have in your life to get a D.
>
> (R. Smith, personal communication, December 5, 2003)

Ruth broke down in tears in my office that day. The DMD curriculum required an intensive drawing studio along with the rigorous math and science requirements, which interfered in her ability to

keep up with her computer science programming assignments. Of all of the students in the study group, Ruth was having the most difficulty transitioning to college which entailed relating to her parents in a new way, finding her own voice and transitioning into an independent learner. Ruth told me that the computer science major had been her parents' idea because of the excellent career opportunities in the field.

Ruth Smith did not join Penn Mentoring, nor did she take advantage of Penn tutoring. By the time she started going to the lab on Tuesday night for homework help, which many students attended throughout the semester, it was too late. Extraordinary ability and achievement in high school had gotten her to Penn but she needed to craft new patterns to succeed here. Ruth elected to drop out of the DMD program at the end of the fall semester and declared a major in Japanese. Despite her bleak assessment of her performance, Ruth ended the semester with a C in CSE 120, her lowest grade. In an interview in spring '04, Amy Calhoun, Associate Director of the DMD program who also sits on the Admissions committee for DMD students, said, "Many of our kids were always used to doing well—all As. When they come to Penn, it's a different story. Everyone here was an A student in high school. The DMD program requires a lot of work." (A. Calhoun, personal communication, April 25, 2004)

The issues presented in this chapter in which students such as Elena, Liz and Ruth, lost confidence and subsequently lost interest in the computer science major may continue into the second year for some students when the curriculum of the major requires students to take even more challenging core courses than those in the first year. By the second year, students in the major generally persist because by the second year their options are more limited if they wish to graduate in four years. However, students at this point in the major may drop down from the BSE degree to the BAS to avoid having to take some advanced core courses. This was the case for Naomi Mathers, who had achieved the highest grades in computer science in the first year among the study cohort and had made the Dean's list in spring '04. Midway through the fall '04 in her second year in the major, Naomi opted out of the Bachelor of Science in Engineering (BSE) for the Bachelor of Arts in Applied Science (BAS) because the BAS program does not require students to take the CSE 381 Operating Systems lab and CSE 371 Digital Systems Organization and Design and the accompanying CSE 372 lab. CSE 380/381 and CSE 371/372 are considered to be among the most demanding core CS requirements, and many students switch from the BSE program into the softer BAS at this point in the curriculum. In October '04, I discussed this issue with CSE 380

Professor Matt Blaze, who told me he thought many computer science majors need more experience in computer programming before tackling the programming assignment in the CSE 381 lab. In a conversation in November, 2004, Professor Max Mintz said, "Students need to practice, practice, practice programming to become proficient enough in programming to handle the more advanced core courses." According to CSE 120 Lecturer Jean Griffin and Naomi's CSE 260 Professor Max Mintz, Naomi was one of the most talented students in their classes, so talented that Jean Griffin had asked Naomi to TA for Jean's CSE 110 Introduction to Programming course in fall'04. In an interview with Naomi in fall'04, in the week she dropped the CSE 381 lab and switched to the BAS program, she told me that she made this decision when she decided not to turn in an incomplete midterm assignment in the CSE 381 lab. A high achieving student, Naomi couldn't bring herself to turn in what she considered less than adequate work, and the stress of this assignment made her realize that earning the Bachelor of Science in Engineering just wasn't worth it to her. Switching to the BAS would allow her to graduate a semester early in December of her senior year and she could reduce the financial burden she was incurring at Penn. Naomi decided that she would teach high school after she graduates from Penn. The daughter of a minister and devoutly religious, Naomi couldn't rectify her notion of a career as a computer science engineer with her desire to work with people and to eventually become a missionary to an underserved population.

Maria Fusco and Naomi had shared all of the ups and downs as Curriculum Deferred engineering freshmen and then as first year computer science sophomores, and Maria was shaken by Naomi's decision to switch to the BAS program. Shortly after Maria turned in her own CSE 381 lab assignment, she popped in my office unannounced to talk. Maria considered Naomi more talented than she, but Naomi's waterloo was the CSE 381 midterm programming assignment, which did not play to her strengths. Naomi is a theory person and CSE 381 relies more on programming skill. Maria filled up with tears when she discussed her friend's decision. "Many of the girls in the class are such perfectionists that they can't turn in something incomplete, something less than perfect. Faculty need to tell them that it is alright, that they'll be alright. I turned in an incomplete assignment and so did most of the other students in the lab. I am afraid I will end up as the only woman in my class who will graduate with the BSE."

Both the participants that persisted and those who did not struggled with maintaining their confidence in their ability to be successful in the computer science major. Three of the ten who persisted,

Maria, Giselle and Lilly, had the advantage that they genuinely liked and did well in computer programming, the subject matter first presented in the major. Moira made the decision to re-take the initial course and also to take a non-required course, CSE 123, to build her programming skills. Maggie decided not to invest the time that computer science required because her dream is to become a medical doctor, and she did not believe she could pursue both computer science and premed. Elena, Liz and Ruth, the students who dropped out of the major, may have been deterred by grades that were less than what they were used to earning. All three women expressed a desire to study in a major that interested them more, although Elena had still not declared another major by the fall of her second year. Achieving a high degree of success in her first year, Naomi abandoned the more rigorous BSE for the flexibility of the BAS in her second year of the major and stated that other than teaching computer science, she could not picture a place for herself in the field. Although this study is restricted to the population of women in the first year of computer science programs, there is considerable evidence that in the second and third year of the major at Penn, attrition occurs most often from the BSE programs as students drop down into the BAS programs with less computer science requirements to complete their undergraduate degrees. Women are especially vulnerable to doing this.

6. Failure to Thrive—the Social Isolation of Women in Computer Science

Women's loss of confidence in their ability to be successful in computer science is also related to the isolation that they experience in the major. Much of learning occurs as students discuss course material and assignments with their peers. For undergraduates the lines between socializing and academic work blur as students naturally share tidbits of information about their academic work, impart anecdotal information about courses and professors, and continue discussions that begin in class. Many women in computer science are effectively isolated and marginalized by being cut out of the informal social peer network where college has a major part of its impact on students. The metaphor "failure to thrive" (Tobias, 1991) aptly describes the harmful effects of social isolation, which students may experience when they hold no membership in a group and have no friends in their major. Examples culled from my interviews and email correspondence with the study participants and also from their own reflections in their computer

science journals demonstrate how some of the participants had fewer opportunities to interact with their classmates over their course work than their male peers. Some students shared instances in which male students left them out of conversation and made them feel invisible, like they did not belong.

Giselle told me in a personal interview in September '03 that she had been dismayed when, at the end of one day during Information Technology Assistant (ITA) training in August, she was not invited to go out socially with her male peers. "After all," they told her, "It's just going to be the guys." Giselle struggled with the fine lines between work partners and social friends throughout the freshman year. Giselle also wrote about other instances of being ignored by her male classmates in her journal.

> October, 2003
> Today, almost two months into the school year, we had our first "group" project in the CSE 130 lab. While it wasn't an actual project but a group discussion of the problem in the lab session, I found myself leaving the lab realizing why it can be so tough for girls to be in computer science. I left feeling lonely and isolated. … While a few of the guys knew each other from outside sources and began to chat easily over topics of mutual interest, I found conversation difficult to begin. Once past asking them their name, which a few timidly answered and none ever asked mine though I am sure not one knew it, I found they would all turn back to one of the other guys to continue chatting. It's odd because even one of the guys that I initially had befriended at the beginning of the year [acted this way].
> (G. Pie, personal communication, October, 2003)

> May, 2004
> I went to a BBQ sponsored by the Dining Philosophers last week and the feeling of arriving alone to an all-male group was, needless to say, a little intimidating…. What makes it worst is that none of the guys in the group really regarded me as a person who was meaning to be there. I felt like I was judged as the token "girl" in the group and even when the guys from my classes came and got together to talk in general or about things I could relate to regarding our class and final, I felt excluded from their conversations and left by the sidelines being a girl.
> (G. Pie, personal communication, May, 2004)

In a personal interview in February 2004, Giselle told me how uncomfortable she felt going to a lab wearing makeup and feminine clothing. She felt her very presence screamed "girl" and not "computer scientist." This past academic year, she has felt like one person with two different roles—the role of a

computer science student and the role of a young woman. For Giselle, these uncomfortable feelings, resulting from being one of the few women in a computer science lab or classroom, create anxiety which can distract a female student and prevent her from optimizing her academic performance.

A male computer science freshman confirmed Giselle's suspicions of some male students being uninterested in interacting with female students over academic topics. In a personal interview in November 2003 I asked this student about his interactions with his peers in class.

> RP: Do you talk to any other students before or after CSE 120 class?
>
> Male Student: Yes, I talk with two or three other guys.
>
> RP: What do you talk about?
>
> Male Student: We talk about the course work. Sometimes I ask them questions.
>
> RP: Did you ever talk to women before or after class?
>
> The student's face reddened and he looked very nervous.
>
> RP: What is it? You can be honest here.
>
> Male Student: I wouldn't talk to a woman in computer science class about course work. No one would expect a woman to know anything.

Attitudes such as that held by this young male student may continue beyond the undergraduate years, extending into graduate school and professional life. A woman computer science professor painfully recalled her experience of being socially isolated in computer science in graduate school. Her recollection authenticates the destructive results that can occur from being an outsider in a computer science venue.

> I was always a solitary person. I didn't associate with other girls or with boys either…I identified with men…I know now that I should have gone into something else. I would have been able to make an impact. I know that I do make an impact in computer science by teaching, but I would have been able to make a greater impact in some other field. Someplace that would have felt right, and not been so difficult. My lack of social networking was what almost did me in. I didn't have anyone to collaborate with and I was totally isolated. Nothing is done on a graduate or professional level without collaboration. Isolation doesn't cut it. You won't thrive. I didn't thrive…I would never tell a girl to go into computer science unless she really loved it—really, really wanted it."
>
> (personal communication, April 5, 2004)

The isolation women experience in their academic programs could continue into their working lives, marginalizing them and preventing them from fully realizing their professional potential (Etzkowitz, 1994, Widnall, 1988). Another Ph.D. student in Penn's Computer and Information Science department,

who experienced difficulty in completing her degree, told me her story. She was in a male professor's research group and she was getting nowhere. Every day she worked alone in her office. She didn't interact with the other students, or anybody else for that matter. She said that the other Ph.D. students were highly competitive in research meetings with the advising professor and she felt that she was shriveling up. Her advisor treated her like anyone else and she wasn't experiencing any lack of courtesy but it didn't seem like she would ever earn the Ph.D. Then she switched to a female faculty advisor and that made all of the difference for her. She joined a research group that was fun, with camaraderie—almost all women—they laughed and joked and worked altogether in their office. She loved it! It felt like someone had pulled up the shades and threw open the windows. Her research picked up and at the time of our interview in June 2004 she was preparing to defend.

Bonding with other female computer scientists nourished this Ph.D. student and helped her achieve success in her academic program. However, the value of all-women support groups was not immediately obvious to the study participants early in the freshman year. In the October 2003 study group meeting, the study participants discussed the option of joining an all-women's mentoring group led by a female Penn Mentor. Elena's comments reveal how one-sided the pre-college academic and social experience is for some women. Elena said, "A women's group for Penn mentoring might be helpful, but personally for me it would never help me. Not because I'm against all women working together. Not for me. I would never join it. In high school, I had almost no interaction with women. It was my course of study. There were no girls. This setting is uncomfortable. I'd rather be with guys. The guys don't see me as a girl because I'm so used to being with them. I work best with guys because I think like them." Several other study participants reported that they shunned women's groups and activities designed to support them because they believe participating in a women's support group is a tacit admission that they are less capable than the men. Like Elena, few of the members of the study group were interested in participating in the all-women Penn mentoring group. Moira said, "I'm very much into women's rights and the rights of minorities but I think women are presented with needing this women's group to stand up for them." Talia added, "There is no guys' group. Why is there a girls' group? I see us just as individuals, not as girls and guys. We are all the same. If you think women need a support group, it's like women need help, they are weaker." Having been educated in an all-girls' independent school, Sonia expressed an understanding of

the value of the all-women's mentoring group. Sonia told the group, "Gender is still an issue. When I was doing the robotics club things, I was in an all-girls team. We could occasionally overhear the other teams and there were several occasions when other all male teams or predominantly male teams would say, we could overhear them, 'hey they are doing pretty well for a bunch of girls.' We could hear them saying these things!" Sonia's story prompted Lilly to reveal to the group that some people had told her that she probably had been accepted to Penn Engineering because she is a woman.

The tone of the conversation among the group grew serious after listening to Sonia's story. Lilly revealed that some people had told her that she probably had been accepted to Penn Engineering because she is a woman.

> Lilly: People have said it probably helped get me in being a girl in engineering which is 85 percent guys and 15 percent girls. It is not what got me in but it helps.
>
> RP: People at home or at school?
>
> Lilly: Both, slightly at home and here too. If it's between you and a guy, they'll pick you. Not a big thing, they say it's a hairline choice. They say that even if the guy is better, they'll probably pick you because you are a girl. Not in seriousness but aside in joking around.
>
> Sonia: I've jokingly said that about myself.

Although several members of the study group eschewed participating in an all-female Penn Mentoring group, the study group meetings served to support the participants through discussions of issues, such as that initiated by Lilly, that separate and isolate female students from the broader group. Although the women in the study group were put off by offers early in the freshman year to join an all women's mentoring group, the Women in Computer Science (WICS) club and focus groups such as the ones I held, their attitudes noticeably changed as the freshman year progressed. An appreciation of the value of all-women's support groups in computer science gradually developed in several of the women. They came to see the usefulness in discussing issues concerning the major and embraced the additional support. By the spring semester, several had joined WICS and Giselle had become the Freshman Liaison to WICS. At Penn, in an effort to understand her own femininity, Elena took women's studies courses that she appreciated and enjoyed. She also made friends with women for the first time through her residential experience. By April 2004, several of the study participants expressed an eagerness for the study group to come together again to talk about their experiences in the first year of the computer science major.

A common practice in computer science courses that also serves to isolate students within a class is the prohibition against working with classmates on computer science assignments. Several of the study participants voiced to me strong disapproval of this prohibition against student collaboration. Hwa said, "I think having group work adds value to learning. Of course, it does have its pros and cons, but it can foster teamwork and leadership, practical skills essential in the real world. In addition, it allows people to get a better understanding of the problem as team members work together on producing the result." (H. Fan, personal communication, May 6, 2004) Sonia expressed her distress that the first year students were no longer allowed to collaborate outside of class in CSE 121 when working on class assignments. Sonia thought this rule was counter productive, explaining, "It is 2:30 AM and you are alone and left with this one piece of malfunctioning code. It is the night before the homework is due. No amount of working the code will change the results. What are you to do?" (S. Johnson, personal communication, February 27, 2004) Talia said, "Well I think it's ridiculous we can't collaborate. I understand how we want to fight plagiarism and all but I think the way the rules were told to us gives the idea that 'nope, I can't help you. I don't wanna get caught and get a zero.' It makes the environment very unfriendly and very hermit-ish just like the stereotypical CS-nerd. I think we should be able to refer to our peers if we have a mental block or don't know where to start when we want to write our code. But just make sure that there aren't any exact replicas of people's code or structure." (T. Ling, personal communication, February 18, 2004) Anita said, "I do enjoy working with others on computer science problems and it really helps to brainstorm and debug each other's code. Something I might have completely missed could be completely obvious to someone right next to me. However, I can also see the importance of learning to think up solutions by yourself and stretch your mind out a bit. We can't just crunch numbers and type code. We actually have to think. And unfortunately, learning how to do that is a solitary affair. However, being exposed to new ideas and ideas other than your own, such as we do when we brainstorm, is also another great exercise for your brain. And it also produces astonishingly original results." (A. Salamat, personal communication, May 4, 2004)
A sophomore woman at Penn, who switched from computer science to systems engineering after the freshman year, partially blamed the prohibition against student collaboration for her reason for leaving computer science. Reflecting back on her experience in computer science as compared to Systems Engineering, she wrote the following in an email in spring '04.

> In systems, there isn't this big rivalry. Women like to cooperate. The women I have worked with like to work together. Computer Science doesn't give you that opportunity. Computer Science explicitly stated you can't work with people. In systems, homework is worth 10 percent of your grade. Tests measure what you know. That's more stress at exam time but no incentive to cheat on homework. Three times a semester, you're in competition, but the rest of the time it's a different atmosphere. Working with someone so you understand the concept is not cheating, but in computer science it is. Friends call and ask for explanation of homework. You explain it, and you understand it better [yourself]—next time you don't get it, you call them and they explain it to you.
>
> (personal communication, May 10, 2004)

Several study participants regarded courses that prohibit student collaboration to be intentionally designed to weed students out of the major by isolating students, competitively pitting them against one another, and depressing students' confidence that they can be successful.

For several of the study participants, isolation from the broader community of faculty and students in the major undermined their motivation to persist. Having fewer opportunities to interact with their mostly male peers, experiencing discomfort from being one of the few women in a computer science lab or classroom and not being able to collaborate with classmates on computer science assignments contributed to the isolation that these women experienced. The computer science faculty is key to alleviating this isolation for first year students and improving the environment of the major.

7. The Role of Faculty in Women's Persistence in Computer Science in the First Year

Just as the study participants passed most of the first year knowing few of their classmates, they also made few personal acquaintances with faculty. In February 2004, I learned through my third set of personal interviews with the study participants that none of the freshmen had had a conversation outside of class with any faculty member, except their academic advisors. Another exception to this was when I insisted that I introduce Ruth and Hwa to their course instructor, Fernando Pereira, one day after they met with me in my office. However, two sophomore women in the study group were more confident and aggressive in pursuing relationships with faculty through seeking them out and engaging them in conversations outside of class. Naomi and Maria had established excellent advising relationships with their

self-appointed advisor, Professor Max Mintz, and they maintained their friendships with freshman advisor and EAS 101 Introduction to Engineering Professor, David Pope. By the sophomore year, students develop more assertiveness in seeking out relationships with faculty.

Although many of the freshmen women in the study group established a good relationship with the Lecturer-Lab Coordinator for CSE 120-130 and CSE 121-131, Jean Griffin, who holds a Master's degree from Penn in computer science, and Associate Director of the Digital Media Design program, Amy Calhoun, they only met two professors in the freshmen year through their experiences in the large introductory lecture classes, CSE 120 (115 students) and CSE 121 (91 students). They did not seek out these professors during their office hours because they feared that they did not have a suitable question to ask the professor, and that he would question what prompted them to come to his office hours. In personal interviews, all of the study participants expressed positive attitudes toward the computer science faculty they had encountered through classes and advising at Penn. Ruth Smith told me that the Penn faculty is "amazing" and faculty's interest in teaching at Penn was the primary reason that she chose Penn over Johns Hopkins where her older sister is enrolled in a computer science major. However, most of the freshmen participants were too shy and timid to reach out to faculty.

There are many documented examples of how assertiveness differs by gender (AAUW, 1991, 2000, Etzkowitz, 2000, Sadker and Sadker, 1994, Seymour & Hewitt, 1997, Spertus, 1991, Valian, 1998, Widnall, 1988). I observed more assertiveness in the first year male students in approaching CSE 120 professor and computer science chair Fernando Pereira for assistance in understanding topics introduced in lecture, opportunities to work on research projects and recommendations for competitive programs. Two students from CSE 120 contacted me in spring 2004 about their intention to apply to the highly selective Management and Technology (M&T) program, which combines an engineering major with a business major in the Wharton School. Both were excellent students. One of these students was a young man who had participated in my male focus group and April 2004 group meeting. The other student was Anita, a participant in my study group. The young man wrote a detailed email to Professor Pereira in which he elaborated on his interests and qualifications for the M&T program and asked Professor Pereira for an appointment. The student subsequently had a lengthy meeting with Professor Pereira that ended in Professor Pereira's agreement to write the student a recommendation for the admission to the program.

Anita, however, decided not to approach Professor Pereira for a recommendation because she told me that she feared he would not remember her from the first semester. The young man was admitted into the M&T program, but Anita was not, although she had made the Dean's List at the end of the freshman year.

Like Anita, Giselle Pie also expressed apprehension in approaching faculty in the department. Giselle frequently discussed with me her interest in working with a computer science professor on a research project but she had no idea how to go about finding a professor with a suitable research project for an undergraduate. I suggested that she go through the department's faculty web sites to locate a professor whose research interested her. Giselle diligently conducted this investigation and set her sights on working in the area of computer vision. From her home in Canada during the summer after her freshman year, Giselle mustered up the courage to email Professor Jianbo Shi and ask him if she could participate in one of his computer vision research projects. In July, 2004, Giselle emailed me that she was amazed that after he received her email, Professor Shi immediately called her on the telephone to discuss her interests. They arranged to meet in person when Giselle returned to Penn in September and by the end of the first week of school in her sophomore year, Giselle was working as a paid research assistant for Professor Shi.

Faculty encouragement is an important factor in students' persistence. As discussed earlier, female students may perceive that they do not have what it takes to be successful in computer science and many suffer from a lack of self-confidence that has little to do with their capabilities and performance. First year students who were motivated by and derived self-esteem from the praise of high school teachers may have difficulty in adjusting to a less personal college atmosphere. Maria Fusco said to me on several occasions, "Faculty need to encourage us more, tell us we're doing okay and that everything will be alright." In the October '03 group meeting Maria said, "No one around here ever pats you on the back and says 'good job.' I never hear 'good job.'"

Because they lacked the courage to approach faculty, most of the participants relied on Teaching Assistants (TAs) to answer their questions concerning course material and assignments. The computer science department invests heavily in this learning support through providing first year students with several TAs and a full-time lecturer, Jean Griffin, to support CSE 120. The TAs are graduate students and upperclassmen that are selected through a competitive process. They keep extensive office hours in the Dance Lab (first year students' computer science lab) and they log in many hours working with students.

As mentioned earlier, a de facto study group sprung up on Tuesday nights in fall '03, the night before the CSE 120 homework assignment was due, mainly because of the loyal assistance and steadfast support of the CSE 120 TAs, closely supervised by Jean Griffin.

Some faculty members reached out individually to first year students in the 2003-04 academic year; others participated in department initiatives to increase faculty interaction with first year students. Professor Stephanie Weirich knew that her freshmen advisees might not approach her except to ask for her signature on their course pre-registration forms. So Professor Weirich invited her advisees in groups of four to "advising coffees" where the students could chat with her informally in a relaxed atmosphere where no one was put on the spot. In the 2003-04 academic year, the School of Engineering and Applied Science asked the departments to designate specific faculty who would only be responsible for advising freshmen majors. These faculty members met in a group in September 2003 to discuss the unique needs of their freshmen advisees. The department invited first year students to advising pizza parties during fall and spring pre-registration where all of the first year advisors were on hand to informally answer students' questions.

In a similar spirit to Professor Stephanie Weirich's "advising coffees," in February 2004 the computer science department held its first "faculty – student chats" to give the first year students an opportunity to meet faculty outside of class and to learn about their research. Seventy five percent of the standing computer science faculty participated by signing up to be available for students during one of five lab periods over a two day period, giving the students in each CSE 131 (second semester, first-year lab) a choice of five computer science faculty with which to chat. The chats brought together all 91 CSE 121 class and 24 faculty members in small groups in labs, faculty offices, lounges, and conference rooms throughout Levine Hall for 45 minute small, informal conversations on faculty research and careers in computer science. The response from the students was overwhelmingly positive and many wrote the faculty to tell them so. Ting Li's note to her advisor Professor Norm Badler, Associate Dean and Director of the Digital Media Design program, to thank him for the "chat" shows the seriousness with which the students approached the small group meetings with their professors and how much the students benefited from the experience.

> Dear Norm,
>
> Thanks so much for holding such a small group meeting with undergrads. As we talked before I've been thinking about my direction. Another factor that would influence my decision a lot is that I always want to balance between the things that I feel I have to do(more academic achievement, like to be a professor just like my parents and my grandparents), and those I desire to do (less academic but really fun, like making great games and movies). I think it might be easier to transform from the first one to the second one while much different for the inverse situation. But I also understand that to achieve the first one itself could take longer than expected as well, and it might take over all my passions for the other dream little by little. Hope to hear from you soon! I am looking forward to having your advice.
>
> Cheers,
>
> Ting
>
> (T. Li, personal communication, February 26, 2004)

It is especially noteworthy how Ting seeks the advice of Professor Badler to help resolve her conflict over following in her parents' footsteps or following her own dreams. Faculty received many substantive notes and comments like Ting's from students following the chats. Hwa Fan wrote the following email to Professor Jianbo Shi after the faculty-student chats:

> Professor Shi,
>
> Hi, this is Hwa Fan, and I just wanted to thank you (and your colleague) for taking the time out of your busy schedule to talk to us about some of the projects you are pursuing at Penn. I really think the experiments you are working on are very interesting, practical, technical, but all the while very entertaining and amusing! It just goes to show that computer science can have countless real world applications (re: human activity, psychology, etc.)! It's nice being able to see that. As a freshman in Digital Media Design, I'm still taking a lot of introductory computer science classes at Penn, so in the midst of programming, I often forget what the point of learning all this is for! Anyways, thanks again for the opportunity. Maybe one day I can work on some experiments as well!
>
> Hwa
>
> (H. Fan, personal communication , February 27, 2004)

As Hwa aptly notes, the faculty-student chats served to demonstrate to students why they were learning the core and what could be in store for them if they persist. The students' responses also invigorated faculty who agreed to hold the chats each semester for first year students. Modeling can be a powerful learning tool. Shortly after the faculty-student chats, the TAs approached CSE 121 Lecturer and Lab Coordinator,

Jean Griffin, to ask her if they could hold their own chats with the first year students following the spring midterms. In March 2004 small groups of students with their TAs took over every available spot in Levine Hall for informal "TA—student chats."

Through interacting with faculty, students learn about the discipline and the career opportunities available in the field. When I questioned the study participants in personal interviews about what they intended to do with a degree in computer science, many revealed that they knew very little about the field or the future professional possibilities that computer science holds. All of the women told me that they expected that a computer science degree would garner them a good job after graduation but most could not visualize or describe what that job would be like. This lack of knowing about the field became a significant deterrent to persistence for students when they were exposed to computer programming in CSE 120, some for the first time. Those who did not enjoy programming assumed that computer science must not be for them, and yet they had little else to look to for a possible fit for their interests in the major. Underclassmen need the mentoring and guidance of faculty to help them to investigate the field and find their place within it to sustain their interest in the major.

8. Establishing Community in Computer Science for First Year Students

The lack of confidence and social isolation that many female students experience in the first year of the computer science program could be ameliorated through welcoming all first year students into a computer science community which supports them. There is evidence that a nascent community among first year students is taking shape in the department. As mentioned earlier in this chapter, many first year students now spend considerable time in the Dance lab, where CSE 120 and 121 students have their recitation section and TAs maintain their office hours. Nearly all of the study participants' friendships in the major were formed through working on assignments after regular recitation classes in the Dance lab. Community in this sense refers to faculty, students, and administrators working collaboratively toward shared, significant academic goals in environments in which competition, if not absent, is at least de-emphasized (Angelo, 1996). There is evidence of such communities thriving throughout the Department of Computer and Information Science at Penn among graduate and undergraduates, in research groups,

labs, special programs and student organizations. A greater involvement of first year students in these communities could improve their academic experience.

Meeting with the participants as a group in fall '03 had encouraged a community spirit among them because the students had an opportunity to meet other women in the program and, as was indicated earlier in this chapter, interacting with other female students in the group meeting had provided them with a degree of support. On April 13, 2004, I hosted a second group meeting and dinner for the study participants, and I also invited the nine male students who had participated in a focus group with me in fall '03. Nine female students from the study group and six male students accepted my invitation. I set the tables in our 307 Levine conference so that the students could sit together and face each other. I asked them to introduce themselves at least three times and they laughed at the fact that they still didn't know each other, still knew so few people in computer science. "Why is that?" I asked them. One male student answered, "CS is a solitary pursuit and not conducive to forming friendships. But it wouldn't be like this if we were allowed to work together. I don't think I am a solitary person, but this year I spend all of my time alone in front of a computer. This isn't me." The students talked about the pros and cons of working in groups. They discussed effective means of bringing students in the major together and Giselle suggested that the New Student Orientation, which the department hosts the day before classes begin, would provide an ideal opportunity to introduce the new students to each other. Giselle asked the group if anyone would be interested in forming a committee to assist the department in planning the New Student Orientation.

The students also discussed the Gas Station problem, their most difficult programming assignment of the spring semester, and how they coped with the pressure of getting their work in the day before the start of spring break. Lilly told the group, "Gas station was soooo cool that I didn't mind doing the work!" At that remark, one of the male student quipped, "Yeah, I was working on the Gas Station in the computer room in my dorm until 6AM and this security guard wanted to know what I was doing." Then he confided to the group that he was seriously considering dropping out of the major. When I asked him what major he was considering transferring into, he responded, "That's the problem. I don't know. There really isn't anything else I want to study at this point…I thought I was pretty smart last August, but now I don't think so." Another male student commiserated with him and said, "Well, when everyone else knows more than you do, you feel that way." I turned to the women and said, "Where have I heard this before?" and my

comment made them laugh. I asked the students how they were different today from the person that walked into Levine Hall in September. Sonia grew serious and answered, "I thought I had been admitted into the DMD program because it was easier to get into than straight CSE. I learned this is not true, and I am just as good as everyone else here." Feeling comfortable with one another in a small group with the freshmen year nearly behind them, the sentiments of the men differed little from those expressed by the women. The program ran from 6 to 8PM, yet the students lingered awhile longer, talking quietly in small groups, discussing the courses they would take in the second year, getting to know one another, engaged, happy. At the April group meeting, many of the comments made by both the male and female students resonated with this study's themes of losing confidence, feeling isolated and experiencing anxiety over whether they could be successful in a major that they considered to be more challenging than anything that they had been presented with before.

9. Changes Made in the Delivery of Undergraduate Computer Science Education at the University of Pennsylvania Since the Commencement of this Study

Significant change in an organization begins at the top through the example, coaching, directives, values and guiding principles of the organizational leader. Eduardo Glandt, the Dean of the School of Engineering and Applied Science, is committed to diversifying both the faculty and the student body and has demonstrated this commitment by placing female faculty in leadership positions in the engineering school, supporting female tenure-track faculty, vigorously recruiting female faculty and supporting initiatives to improve the experience of engineering undergraduates.

Dean Glandt brought in Fernando Pereira, former head of a research group at AT&T Labs, to ramp up the Department of Computer and Information Science in the wake of the technology boom but by the 2001-02 academic year, when Fernando Pereira came aboard as chair of the department, the technology bust was underway. The school's plan for the department was to increase faculty, research funding and the quality of its undergraduate programs and thereby the stature of Penn's computer science department. Among the many pressing issues confronting the new chair was the redesign of the department's undergraduate education. The chair chose to teach the introductory course, where attrition from the major is highest, sending a strong message that undergraduate education was a priority for him. Having taught

CSE 120, the first required computer science course for majors for two years prior to this study, Fernando Pereira was aware that his students were beginning the major with varying levels of prior experience from high school, making it more difficult for students with little background in computer programming to succeed. Commencing in the fall '04, the year following this study, Professor Pereira devised the following multiple pathways into the major for first year students:

1. Students with significant prior experience in computer programming can waive CSE 120, Introduction to Programming Languages and Techniques I, the first required course, by either passing a placement test or scoring a 5 in the AP computer science Java exam. These students now have the option of beginning their fall studies in computer science on a more advanced level with CSE 240, Introduction to Computer Architecture, or CSE 260, Mathematical Foundations of Computer Science, and CSE 121, Programming Languages and Techniques II in spring.
2. Students with some experience in computer programming from high school can enroll in CSE 120 in fall and CSE 121 in spring.
3. Students with no prior experience in computer programming can enroll in CSE 110, Introduction to Computer Programming in fall, a less theoretical Java programming course. Students who opt for CSE 110 and who earn at least an A- in the course may proceed to CSE 121 in spring. Students who earn a B+ or less in CSE 110 may continue in the major by taking CSE 120 in the following fall.

The computer science department mailed a brochure describing these alternatives to all first year students in summer '04 and also posted this brochure on the undergraduate computer science website. The department chair anticipated that accurate placement of incoming students would improve the retention of students in the first year of the major and records show a decrease in the numbers of first year students leaving the major in '04-'05, the first year that this plan was implemented. This plan also provides a pathway into the major from CSE 110, the programming course also taken by non-majors, thereby funneling additional qualified students into the major who had not previously considered it.

Fernando Pereira, along with the undergraduate chair, Sampath Kannan, achieved another significant change in undergraduate education through redesigning the undergraduate curriculum and the core courses required in the first two years of the major and entrusting the teaching of the core to a combination of seasoned professors and tenured track assistant professors in the standing faculty who are

noted for excellence in teaching. Professor Kannan reviewed the curriculum of the second year core courses, combining courses with significant overlap, examining core courses for academic requirements for which students may not have had adequate preparation through previous courses, and adding recitation sections to some core courses. Through eliciting feedback from students and faculty during 2004-'05, the first academic year in which these curricular changes were instituted, and through closely evaluating students' progress, the department found evidence that these modifications were positively influencing students' performance and attitudes toward the major.

10. Comparison of the Study Group to the Rest of the First Year Computer Science Class

This chapter described the study participants' experiences in their first year in computer science at Penn and investigated the issues that impacted on their success and satisfaction in the program. The ten participants, who persisted in the computer science major, exhibited great personal resiliency by adopting a myriad of methods of coping academically and emotionally in the first year. Some students looked outside of the department for comfort and companionship. Sonia drew a degree of strength from her leading role in a Penn student drama. Maria and Moira threw themselves into sorority activities to escape loneliness and to fully participate in something larger than them. In contrast to this, Hwa and Anita developed a single-minded determination to succeed in the major, putting their computer science work above all else. Sonia also attended many more labs and study sessions than were required to ensure her success. Moira, Maria and Naomi developed a calculated strategy to be successful, which included seeking out faculty for personal relationships and taking extra non-required computer science and engineering courses to develop the confidence that they belonged. Giselle became a leader in the Women in Computer Science organization and engaged department faculty and staff in organized attempts to elicit change. Making the decision not to become thwarted by grades that were lower than they were used to bolstered Maria's and Talia's persistence. Embracing the support of graduate students in the department and maintaining the ties with her computing buddies in mainland China made the difference for Ting. Finally, the pure love of programming aided Lilly's, Giselle's and Maria's efforts in the first year.

Following is a discussion on how these women fared in terms of grades and grade point average as compared to the rest of the first year CSE class. The initial enrollment in CSE 120 was 122 students. After

the fall drop/add period, 115 students were enrolled in CSE 120, 91 men (79 percent) and 24 women (21 percent). Of the 7 who dropped in the first two weeks of class, 2 were women (not in the study group) and 5 men. After the first midterm, 1 woman (in the study group) and 3 men dropped CSE 120. In spring after the drop/add period, 90 students were enrolled in CSE 121, 76 men (84.4 percent) and 14 women (15.2 percent). Twelve of the women enrolled in CSE 121 had persisted from the original 24 women in the fall term--50 percent persistence to the spring term. The remaining 2 women in CSE 121 had taken CSE 120 in a prior year. Of these 14 women in CSE 121, 9 were members of the original 14 member study group (64.2 percent persistence), 3 were part of the 10 women who did not choose to participate in the study (30 percent persistence), and 2 had taken CSE 120 in a previous year. Of the 91 men in CSE 120 in fall '03, 61 enrolled in CSE 121 in spring (67.7 percent persistence). Of the remaining fifteen men enrolled in CSE 121 in spring '04, six had waived CSE 120 (via placement exam) and nine had taken CSE 120 or its equivalent at another college in a previous year. Although the number of students in CSE 121 was 78 percent of the number in CSE 120, the new students who enrolled in the second course masked the magnitude of the attrition of the students from the original fall group in CSE 120 who did not persist to CSE 121. The overall persistence of both men and women from the first to the second course was 63 percent.

By spring semester '04 the percentage of women in the first year computer science class was 15.2 percent, down from 21 percent of the class in September. The persistence of the entire group of women from CSE 120 directly into CSE 121, the recommended course track, was 50 percent, while the persistence of the men from CSE 120 directly into CSE 121 was 67.7 percent. However, when the persistence of the participants in the study group are viewed apart from the other women in CSE 120, the persistence of the study group participants from CSE 120 directly into CSE 121 is 64.2 percent, much closer to the persistence of their male counterparts. One of the five students in the study group that did not continue directly into CSE 121 took this course in the spring of 2005, although she is not counted in the persistence statistics of the study group in this analysis.

The following table depicts the female students' performance in the individual course grading components. These consisted of two midterm examinations and one final examination in each course. Course homework assignments were also factored into configuring the final grades in each course. As compared to the class, the study participants performed as follows:

Table A: Study Group's Mean Scores in Comparison to Class Mean Scores

CSE 120	Study Group	Class
Mean: Fist Midterm	73.2	78.5
Mean: Second Midterm	73.3	76.2
Mean: Final Examination	78.3	79.5
Mean: Final Grade	79.26	80.52
CSE 121	Study Group	Class
Mean: First Midterm	67.7	72.53
Mean: Second Midterm	73	78.16
Mean: Final Examination	157.6	151.5
Mean: Final Grade	80.94	79.93

In addition to persistence statistics that nearly mirror the class, the performance of the study participants, as a group, steadily improved throughout the course. In both the CSE 120 and 121 courses, the mean of the study participants at first lagged behind the class mean, but caught up to the class by the end of the semester, finishing the fall course within a fraction of the class mean and the spring course a point above the class mean. The improvement of the women's mean score as each course progressed could indicate increasing confidence levels in these students.

Study Participants' Individual Results at the End of the First Year

As a group, the participants completed CSE 120 nearly at the class mean and completed CSE 121 slightly above the class mean. The following table depicts the study participants' individual performance in the first year of the computer science major. The fall grades of the five students who did not persist to the second course in spring are C, C+, and two B+ grades. The fifth student did not complete the fall course.

Table B: Study Group's Individual Results at the End of the First Year

Student	Fall'03 Incoming Major(s)	CS 120	CS 130 lab	CS 121	CS 131 lab	Fall '03 GPA	Spring '04 GPA	Incoming SAT V/M	#AP credit
1*	WH/CSE	B+	A+	A-	A-	3.56	3.86	760/790	
2*	DMD/Wh	A	B+	A	A	3.87	4.00	640/740	
3	CSE	A-	A-	B	A-	3.21	2.57	680/730	1
4	CSE/Undc	B+	B+	B	B	2.63	2.26	770/800	
5	DMD/Undc	B+	A+	--	--	3.41	3.75	590/800	2
6	CSE	B+	A+	B+	B+	2.94	2.44	660/740	
7	ASCS/Undc	B+	A+	B-	B-	3.40	3.26	640/800	1
8	DMD	B+	A+	B	B	3.33	3.42	720/760	
9	DMD	B+	A+	B+	B+	3.37	2.93	NA	1
10	DMD	C	B	--	--	2.69	3.85	700/680	
11	SAS	--	--	--	--	2.83	3.26	620/650	1
12*	CSE	A-	A+	A-	A-	3.76	3.83	630/730	1
13	CSE	B+	A+	--	--	3.45	3.80	770/710	9
14	CD/Undc	C+	B+	--	--	2.85	2.58	770/730	4

NB: CSE 130 and 131 are the .5 credit unit (CU) labs accompanying the 1.0 CU CSE 120 and 121.

Notes:
* indicates Dean's List
WH: Wharton major
Undc: School of Arts and Science Undeclared Major
CD: Curriculum Deferred in School of Engineering and Applied Science
CSE: BS in Computer Science Engineering major
DMD:BS in Digital Media Design major
ASCS: BA in Applied Science Computer Science major

Two of the five students who did not persist from CSE 120 to CSE 121 earned B+ grades and high grade point averages, performing as well as the majority of women who persisted and indicating that academic performance was not the determining factor in these students' attrition.

All Women Who Enrolled in CSE 120 in Fall '03 but Did Not Enroll in CSE 121 in Spring '04 (figures represent enrollments after the fall two week drop/add period)

The following table depicts the grades of all of the women (study participants and non-participants) who did not persist from the first to the second computer science course. The female students who were not in the study group had a lower persistence than the students in the study group. The students from the College performed lower in terms of grades than the students from the School of Engineering and Applied Science and the lone student from Wharton. The fact that these students from the College did not have the benefit of SEAS freshmen orientation and they did not have a SEAS advisor could have impacted on their performance. Only four of the eight SEAS women who did not persist had a declared major in computer science in fall '03, indicating, perhaps, that the students who did not persist had less focus on the computer science major. However, all of the students knowingly enrolled in the first course in the major, even though a programming course for non-majors was available. In addition, all of the study participants indicated to me that they were interested in majoring in computer science, even those who had not declared the major.

Table C: Academic Results at the End of the Fall '03 Semester of Women Who Did Not Enroll in CSE121

SEAS	**Major fall'03**	**Year**	**CSE 120 grade**	**In study group**
1	CD	F	A+	No
2	DMD	F	C	Yes
3	SSE	J	A	No
4	DMD	F	F	No
5	ASCC	F	B	No
6*	CD	F	B+	Yes
7	CD	F	B+	No
8*	CSE	F	B+	Yes
Wharton				
9	Wharton	J	A-	No
College				
10	Undeclared	J	C	No
11	CD/Undc	F	C+	Yes
12	Biology	So	Dropped course	Yes
13	Economics	S	D	No

Notes: SSE: Systems Engineering major; ASCC: Computer & Cognitive Science
F indicates freshman; So indicates sophomore; J indicates junior; S indicates senior

Unlike the women, the majority of the men from the School of Engineering and Applied Science in CSE 120 who did not persist to CSE 121 had a declared major in computer science (11 out of 17). The occurrence of low grades (C or lower) is more evenly distributed among the male students from SEAS and the College. However, 8 of the 17 SEAS men who did not persist, as well as a student from Wharton and a student from the College earned a grade of A-, A, or A+ in CSE 120. 4 of these students had declared majors in computer science, making them likely candidates to continue with computer science.

Table D: All Men who Enrolled in CSE 120 in Fall '03 but Did Not Enroll in CSE 121 in Spring '04 (figures represent enrollments after the fall two week drop/add period)

SEAS	**Major fall'03**	**Year**	**CSE 120 grade**
1	CSE	J	A
2	DMD	F	F
3	ASBS	So	F
4	INDM	S	A+
5	ASCS	J	A
6	BE	J	A
7	CSE	F	B
8	CD	So	Dropped course
9	CSE	J	A
10	EE	F	A-
11	CSE	F	F
12	CSE	F	B-
13	CD	So	A+
14	CSE	F	C
15	CSE	F	D
16	CD	F	B-
17	CSE	J	A
Wharton			
18		So	B
19		F	Dropped course
20		F	A-
College			
21	Undeclared	So	C+
22	Undeclared	F	A
23	Undeclared	F	B+
24	Undeclared	F	F
25	Undeclared	So	B+
26	INSP	S	Dropped course
27	Philosophy	S	C+
28	Undeclared	F	B+

Notes:
ASBS: Applied Science Computational Biology
INDM: Individualized Major
ASCS: Applied Science Computer Science
BE: Bioengineering major EE: Electrical Eng.

F indicates freshman
So indicates sophomore
J indicates junior
S indicates senior

Behind the Numbers--Analysis of Attrition

Does any pattern in terms of academic performance or time left to complete the undergraduate degree emerge among the students who did not persist? Do the male students who decided not to continue with computer science look any different from the women who did not continue? Twelve women completed CSE 120 and did not enroll in CSE 121, the second course in the major sequence. Of these students, 58 percent (seven students) had grades of B- or better. Five of these seven female students were freshmen and sophomores, the most likely class years for students to select the computer science major. Twenty-five men completed CSE 120 and did not enroll in CSE 121. Of these students, 68 percent (seventeen students) had grades of B- or better. Eleven of these seventeen male students were freshmen and sophomores, again likely years for students to select the computer science major. Students may begin the computer science degree in the Junior year, but it is unlikely that they would be able to complete the undergraduate program in four years of college. While it is impossible to ascertain exactly how many students the department lost who had the intent to major in computer science, sixteen of those who did not continue into the second course (31 percent of the women and 44 percent of the men) performed well enough in the first course *and* were early enough in their undergraduate careers (freshmen and sophomores) to select the computer science major. In addition, three women (25 percent) and 10 men (40 percent) who did not persist earned a grade of A or A-, and 5 of these were underclassmen, suggesting that something other than academic performance factors into students' decision to continue with the major. Male students performed only slightly higher than female students in terms of earning a grade of B- or better in CSE 120 (68 percent of men as compared to 58 percent of women).

In summary, the total attrition from CSE 120 to CSE 121 was 37 students or 32.1 percent of the original class of 115 students; sixteen students or 13.9 percent of the class earned a B- or better in CSE 120 and were underclassmen, indicating that they did well enough academically to persist and had enough time left in their undergraduate careers to choose the computer science major and graduate on time. The most significant difference between men and women was not their performance in CSE 120. The most significant gender difference was in the low percentage of women enrolled in CSE 120 after the fall drop/add period (21 percent) and the even lower percentage that chose to continue to CSE 121 (15.4 percent).

11. The Role of the Researcher in this Study

The women in the study group had a much higher persistence rate from the first to the second course than those who did not participate in the study (64.2 percent vs. 30 percent), leading one to question what role, if any, participation in this study had on a female student's decision to persist. In addition, a 10th member of the study group rejoined the major in the 2004-'05 academic year and the other 9 participants remained in the major throughout the second academic year bringing the study group's persistence to 71.4 percent. Through the series of interviews, group meetings and email correspondence that stemmed from conducting this study, I came to know each of the participants personally. I shared the ups and downs with them of the first year in the major, cried with them and rejoiced in their success, and I am still closely involved with many of them now in their second year of the program. The numbers are far too small to draw the conclusion that participation in a study group improves students' persistence in the first year of the computer science major. The motivation and commitment to persist in the members of the study group could have exceeded those women who chose not to participate, prompting them to invest the time in working with the department to improve the success of first year students in the major and to persist. In addition, something akin to the Hawthorne Effect may have been operating whereby the very act of being singled out and attended to by departmental faculty and staff could have encouraged these students to persist, at least for the duration of the study. However, having someone administer to an underrepresented cohort of students who is invested in their success, who brings early intervention to bear for those who need it, and to whom they can safely express their views and feelings, can only aid the persistence of these students.

The themes of this research study suggest that many women begin the computer science major with an inadequate background from high school in the subject, causing them to struggle to perform as well as their peers with more computer science experience. Because of this fact which is further heightened by the women's perception that the male students know more than they, women may lose confidence in their ability to be successful in the major and subsequently lose interest in the major. Social isolation accompanies their minority status within their peer group further weakening their resolve to persist. However, this research also suggests that creating more entry points into the major which allow students to

begin their studies with others at the same level, and creating more opportunities for a community to develop which is characterized by more frequent interaction for students with faculty and peers, could support the retention of women in the first year of the major. This study also suggests that the issues that undermine women's persistence may also be undermining that of some male students and they may benefit from the same initiative designed to support women. In the next chapter I will explore the means by which the Department of Computer and Information Science, the School of Engineering and Applied Science and the University of Pennsylvania could best support these students.

CHAPTER FIVE

FINDINGS AND RECOMMENDATIONS FOR INSTITUTIONAL PRACTICE

This final chapter summarizes the findings of this research study and provides recommendations for Penn faculty and administrators on how they can encourage women to study computer science, support their efforts and promote their success and satisfaction in the discipline. Because an interest in computing often begins in high school, this chapter also offers high schools and computer science teachers recommendations on how they can engage girls in the study of computer science and prepare them for success in the major in college.

Findings

This study addressed the nature of women's experiences in the first year of a computer science program in a selective university and how their persistence could best be supported. Throughout the 2003-04 academic year, I worked closely with fourteen first year women in the computer science program at the University of Pennsylvania and carefully recorded their experiences. All but one participant completed the first required computer science course in fall'03. Four others completed the fall course but chose not to enroll in the second required computer science course in spring '04. One of these four returned to take the second course in her sophomore year. The remaining nine students successfully completed both the first and the second course in the recommended sequence. Following is a summary of the findings of this research study.

The encouragement of their fathers factored heavily in several of the study participants' choice of the computer science major.

Twelve of the fourteen students came from highly educated families and half of the participants' fathers are computer scientists or engineers. These women reported a close affinity to their fathers' interests from elementary school through high school, and their fathers' enjoyment of computing and

positive attitudes toward the rewarding career prospects for their daughters in the field influenced their selection of the computer science major at Penn.

Excelling in mathematics in high school was the most important influencing factor for the study participants to pursue computer science in college.

The women who participated in this study are all high achieving, multi-talented students who could have pursued many majors in college. However, their families and middle and high school teachers nurtured their aptitude for mathematics, and excelling in mathematics in high school was a major factor in their decision to study computer science at Penn. A strong link exists between mathematical and problem solving skills in girls and an interest in computing. Girls' mathematical self-concept is also closely related to their choice of a science and engineering major in college (AAUW, 1991; Astin, 1992; Sax, 1994; Seymour & Hewitt, 1997). While in the past girls have lagged behind boys in taking advanced courses in mathematics in high school, this is no longer the case. The achievement gap between males and females in mathematics from eighth grade through high school has narrowed; both male and female high school students have experienced equivalent gains in completing mathematics courses, including algebra II, precalculus and calculus, generating a substantial pool of female students qualified to study quantitative majors such as computer science (NSF, 2002).

An Interest in the applications of computer science drew these women to the major.

Most of the study participants were attracted more to the applications of computer science than to the computer itself. They expressed the desire to apply computer science to solving problems in cognitive science, robotics, artificial intelligence, biocomputing and the arts. These students wanted a broad education and chose Penn because of the multi-disciplinary environment of the university, providing students the opportunity to study in both the Engineering school and Wharton, the School of Fine Arts or the College. However, they worried that they were not passionate enough about computer science because they did not share the same intensity for computing activities such as programming and computer games that they perceived in their male peers.

An inadequate pre-college background in computing caused the women to begin the major with less experience than many of their male peers.

Girls are not well represented in computer courses and clubs in high school, and consequently are less prepared than males for the major in college. In addition, many high schools do not offer an adequate program for students bound for majors in computer science. Several of the participants reported that prior to college they did not participate in computing courses and robotics clubs because they did not have enough experience in high school to compete with males. Peer pressure discourages girls' involvement in a pursuit that many girls consider to be the domain of obsessive, socially disconnected and myopically focused geeks who adopt an unhealthy lifestyle devoid of interpersonal interactions in a 24/7 connection to the computer (AAUW, 2000; Margolis & Fisher, 2002; Seymour & Hewitt, 1997).

Although some of the women were exposed to computer programming in high school through the AP A computer science course, only one of them took the AP AB advanced course. Females make up only 12 percent of AP computer science AB exam takers (Fisher, Margolis and Miller, 2000). In the first required course in the computer science major at Penn, no previous experience with computing was required, yet many of the male students in the class actually had a great deal of prior experience from high school, while other male students claimed to have this prior experience. Both academically and emotionally, the disparity in prior experience with computing in the first year class worked against the study participants' motivation in that they found it very difficult to keep up with many of their classmates, and they perceived that the introductory course did not afford them a level playing field on which to compete. A study, conducted by MIT's Department of Electrical Engineering and Computer Science faculty to examine the imbalance in male and female undergraduate enrollment, found that many MIT undergraduates felt less prepared than their peers to major in electrical engineering and computer science, but the women felt this way much more so than the men. The report states, "Although it is probably true that women, on the average, come to MIT with less experience in EE and CS than do men, it also seems true that such a difference in responses must be due partly to perception rather than reality (MIT, 1995)."

Financing the degree did not prove to be am extraordinary issue to most of the study participants.

Generous financial aid packages from the university along with the middle to upper income bracket of most of the study participants' families mitigated the stress of financing the undergraduate education at Penn for most of the women in my study group. Only two students complained of having to work to finance their education. These students received financial aid from Penn and support from their families, but they also had to take out loans and work. Some of the students expressed temporary financial problems in their families because of the technology downturn. One student's mother and one student's father was out of work in September '03, but these situations eased as the year progressed and their parents found new positions. Many of the study participants came from highly educated families who paid for all or a great deal of their education. Penn gave generous financial aid, including Trustees Scholarships, to several of the students who would not have been able to afford a Penn education.

Most of the women struggled in the first year of their computer science courses to maintain the confidence that they could be successful and consequently to maintain their interest in the major and their belief that it was a good fit for them.

The mean of the study group in the course examinations in both the first and second computer science courses at first lagged behind the mean of the class. However, by the end of the first course, the mean of the final examination and final grades of the study group caught up with the mean of the class, and in the second course slightly surpassed the mean of the class. Yet many study participants feared that their less than perfect grades in the first year courses were a signal that they did not have the aptitude for the major. Research shows that GPA in engineering courses is the single greatest predictor of persistence in engineering majors for both women and men and where the grades are the same, there is no difference in the persistence rates of women and men (Davis et al, 1996; Sax, 1994; Strenta et al, 1994). However Seymour & Hewitt (1997) found that differences in performance scores are insufficient to predict attrition in science, math and engineering majors and women who leave often have grades as high, or higher, than the average man who persists. Goodman et al (2002) found that women who find their grades discouraging are more likely to leave engineering majors than those women who do not find their grades discouraging, even when they have equivalent grades. Margolis & Fisher (2002) found that women who cite a lack of

interest as their reason for switching from computer science mask a complex process by which their enthusiasm for the major quickly diminishes in freshman year and is replaced with an abiding lack of confidence when these women, who had once been the best and the brightest among their high school peers, now find themselves surrounded by classmates who seemingly know more than they.

Academic support fell short of that needed to sustain women's success.

The Penn Mentoring Program (PMP) provided a measure of academic support for several of the participants. The CIS department worked closely with Myrna Cohen, Director of the Learning Resource Center, in carefully selecting and training the Penn Mentors who met weekly with small groups of first year students, and faculty and teaching staff strongly encouraged first year students to participate. Because of the direct involvement of the CIS department with the Learning Resource Center, the PMP effectively supported first year computer science students.

The students also received a great deal of support from the Teaching Assistants who were assigned to their recitation sections. The Dance Lab (first year lab) was a home for first year computer science students, a place they could always expect to find open and to get help. TAs held their office hours in the Dance Lab, a lively place usually filled with students at any time of the day or night. In the lab on Tuesday nights during the 2003-04 academic year, friendships took root as camaraderie developed among students. The lab also provided an ideal place to host the study snack breaks that the Women in Computer Science organization often provided the students.

Although the Penn Tutoring Center provided tutoring for the first year computer science courses, these services were not well advertised to students by the department or the school and consequently did not provide them with enough support. It is critical that both the department and schoolwork with the Department of Academic Support Services to ensure that students receive the support they need to be successful and to get the word out to students that they should take advantage of these services.

Many students continue to need support to acquire the required skills to be successful in the second year core courses. Computing, a dynamic field, changes rapidly, and students need continuous exposure to new software packages, programming languages and methods. Many students are able to "pick up" on their own skills that impact their performance in core courses. Faculty has expressed concern that

some students, not only in the first but also in the second year of the program, must spend inordinate time on assignments because of a lack of programming experience and familiarity with computing tools. One study participant, who persisted into the second year of the program and who had excellent grades in her computer science courses, made the decision to drop down from the Bachelor of Science in Engineering degree program to one of the Batchelor of Arts in Applied Science programs which requires fewer technical courses and labs. She and other students who made or seriously considered this programmatic change reported that they did not feel prepared enough to be successful in some of the projects and assignments required in the second year core courses and they needed to spend inordinate time (30 hours per week or more) to complete a single assignment.

Social isolation from faculty and peers in the computer science major made the first year of study difficult for many of the women.

Social isolation was partially the result of the students' gender minority status in that they became acquainted with few of their classmates, and they were not included in many of their male classmates' discussions and activities. They were too timid to insert themselves into social situations with their classmates, and the first year courses did not facilitate enough interaction among students. Course prohibitions against student collaboration on most course assignments further compounded this problem. Students were required to work alone on homework programming assignments in the first year courses, referring questions only to their instructor or course TA. Working with another student usually constituted cheating, even though many of the students were struggling with the same material. In addition, this approach to programming gave students the mistaken impression that software engineers work alone in an isolated environment, since almost all software projects in industry require teamwork and collaboration. In a study evaluating the beneficial effects of collaborative learning vs. individual learning in an industrial technology course, Gokhale (1995) found that both methods of instruction were equally effective in gaining factual knowledge, but that collaborative learning fostered the development of critical thinking through discussion, clarification of ideas, and evaluation of others' ideas, and also had the added benefit of reducing students' anxiety associated with problem solving.

In the beginning of the academic year, the participants were not interested in joining all-women academic and social support groups because they believed that doing so would be a tacit admission that they needed additional support because they were not as academically capable as the male students. Many did change their opinion by the end of the academic year and joined the Women in Computer Science organization. However, the women were spread thinly throughout the CSE 120 and 121 recitation sections and most became acquainted with few other women in the class during the first semester. Although the students enjoyed their residential experience at Penn, they were also spread thinly throughout the university. The residential experience helped them bind with the broader university, but did not especially support their affiliation with the School of Engineering and Applied Science or the Department of Computer and Information Science. Therefore, most of the participants passed the first semester and a good part of the second semester making few, if any, friendships or contacts in engineering or computer science.

The freshmen participants also had little contact with faculty, and again they were too timid to reach out to faculty in office hours or informally outside of class. They all expressed positive impressions of Penn faculty, but the freshman year presented them with little opportunity to actually interact with faculty outside of class. This was not the case for the sophomore participants who confidently pursued personal relationships with their faculty advisors and instructors. The single most critical need that women expressed throughout Seymour & Hewitt's study (1997, p. 305) was the need for a supportive, personal relationship with their faculty. Men and women diverge in what they expect of the faculty-student relationship and in the consequences of their unmet expectations. While men describe a "good" professor as one who is "enthusiastic," "interesting," "entertaining," and "can explain well," women's definition of a "good" professor is one who is "approachable," "friendly," "patient," and "interested in how you respond." A Harvard study also found clear differences in what male and female Harvard undergraduates expressed that they wanted in a relationship with a faculty advisor (Light, 17, 1990). When asked about advising, men responded that they want an advisor who "knows the facts," or "if he doesn't know the data, he knows where to get it or to send me to get it," or one who "makes concrete and direct suggestions, which I'm then free to accept or reject." Women, in contrast, responded that they want an advisor who "will take the time to get to know me personally," or who "is a good listener and can read between the lines if I am hesitant to

express a concern," or who "shares my interests so that we will have something in common." The women's responses showed that they focused far more on the importance of a personal relationship with the faculty advisor.

Recommendations for Institutional Practice

These study findings suggest a two-prong approach to answering the research questions: 1) given that students who study computer science have varying degrees of background and prior experience with the subject, departments of computer science should place students in the course that fits their prior background and experience, thus giving every student an equal opportunity to be successful, and provide academic support to students when they meet challenging material which is new to them, and; 2) given that women are in a gender-minority in computer science programs and may experience isolation from peers and faculty because of this, schools and departments of computer science should actively welcome new students into a community which supports them both academically and socially. These findings have specific implications for schools and departments of computer science that are committed to supporting the success of their female students.

In Penn's computer science department, as in most other selective departments and schools of computer science, applications to computer science programs swelled in the late 1990s due to the technology boom, and enrollments in the undergraduate programs doubled by the year 2000, stretching departmental facilities and instructional staff. Coping with the sudden surge of students with varying backgrounds and motivations for studying computer science stretched the department's resources and attrition increased. The School of Engineering and Applied Science responded quickly by ramping up facilities and recruiting a substantial number of new faculty. The technology bust occurred as quickly as did the technology boom only a few years prior. With a much larger faculty and state of the art computer science facilities, Penn's Department of Computer and Information Science is reconsidering key areas in its delivery of undergraduate education that could result in a better academic experience for computer science majors.

The following discussion looks at opportunities for faculty, administrators, and students to exploit Penn's strengths and institutional resources to maximize the positive outcomes of persistence and satisfaction for women in the major. This section also speaks to high schools and computer science teachers, suggesting how they could encourage and guide young women to the study of computer science.

Recommendations for Faculty and Administrators

Design multiple pathways into the computer science major to address first year students with varying prior experience with computer science.

Introducing students to the computer science major by placing them in an introductory course that matches their prior experience with the course material gives all students an equal opportunity to be successful, thereby increasing their confidence and their interest in the major. This is especially true for female students who often have less prior exposure to computer science from high school than males. Gurer & Camp (2001) found that misleading course prerequisites, even in basic computing courses, assume a certain level of knowledge that many female students have not yet obtained, compounding the negative effects that a lack of computing experience and skills may have on female students.

Support student learning through a coordination of academic support services by the university, the school and the department so that students receive the academic help they need to be successful.

The University of Pennsylvania offers students unparalleled resources and services to support their success. However, these resources are scattered throughout the university and students may not be cognizant of how and when to access needed support. Schools and departments need to coordinate the delivery of centralized university services to effectively assist those students in need of them. This is particularly important for female students who have higher attrition in the major. The academic department is the first source of information on its students and courses and therefore in the best position to recognize when students need support. Departments need to share in the responsibility with central school administration in assessing students' academic needs and coordinating the delivery of appropriate university services to students.

Labs play an important part in a first year student's introduction to the major. Since they usually contain less than twenty-five students, labs offer an ideal setting for students to get to know one another and also to get the additional help they need to master the course material, perform competently in the homework assignments and prepare for course examinations. The CIS department should consider investing further in the CSE 130 and 131 lab recitation sections that support the first year courses by increasing the numbers of TAs assigned to these labs to keep all recitation sections small, at 8 to 10 students. EAS 101 Introduction to Engineering Professor David Pope experienced a large degree of success in retaining Curriculum Deferred (CD) students within the engineering school by keeping EAS 101 lab sections small, thereby increasing the support per student. Professor Pope said, "It is a lot less expensive for Penn Engineering to pay TAs than to loose enrolled students." (D. Pope, personal communication, April 16, 2005)

Similarly, departments need to continue to support students in the subsequent core courses in the second year by ensuring that students are adequately prepared to handle the new material in each core course. For students who require additional support, the department should provide tutorial sessions and labs on specific topics with which many students are unfamiliar, rendering students more capable to perform in the core courses. Supporting students' competence with computing tools throughout the core is an area worthy of further consideration on the part of faculty because not only first year students but also capable second year students may find an unleveled playing field in some core courses which erodes their confidence. In sharing responsibility for learning with students, faculty transmit their own passion for the discipline to their students and thereby inspire a likewise commitment in their students. In their essay, "Teaching and Learning the Unfamiliar," Lazerson and Wagener (1998) point to two preconditions which faculty must meet in order to make the alien familiar for their students. "The first is creating a classroom climate of trust and safety. Students should feel secure enough to take risks and to go over the edge into the unknown…Repeatedly going down unfamiliar paths, however, requires a second precondition, an emotional investment in learning." It is only through acquiring a passion for new knowledge that students will risk "the uncertain journey of repeatedly going down unfamiliar paths."

Welcome first year students into a computer science community composed of students and faculty that encourages informal interpersonal interaction, giving students the opportunity to get to know their peers in the program and to interact with faculty outside of class.

Social and emotional support factors importantly in student success in college. Interpersonal interaction with faculty and peers breaks down barriers of isolation for women, and increases their comfort level in the major. Welcoming students early in the freshman year into a community of learners comprised of faculty and students, men and women, which serves as a forum to share ideas, solve problems, feel comfortable with each other, engage in the process of becoming a computer scientist, and have fun doing it, would impact positively first year persistence. Opportunities to interact with faculty and peers increase as students move through the computer science programs. However, engaging students through such a community is especially important in the first year when most student attrition from the major occurs. The department should also mass female students in a few recitation sections in the first year, thereby giving them more opportunity to get to know one another. The literature on the impact of college on students demonstrates that learning, academic performance and retention rates primarily are associated with students' interactions with their peers, with faculty, and with involvement in out-of-class activities (Astin, 1993; Pascarella & Terenzini, 1991; Tinto, 1993).

The department should enlist the aid of student groups in developing a sense of community. Student groups almost always guarantee student attendance and the department should involve them in developing community-building initiatives for students. Student leaders have shared with me that they are honored when faculty see their organization as a resource in improving the academic program. Faculty should partner with student organizations to sponsor and promote events like faculty research talks designed specifically for undergraduates, student-faculty coffee breaks during midterms and examinations, and departmental town meetings to explain and discuss curricular changes and new courses with students. Departments should support female students' organizations such as the Women in Computer Science at Penn. This organization offers first year women peer mentoring and access to professional women and networking opportunities in industry.

Increase students' opportunity to work collaboratively on course assignments and projects.

While students usually worked alone on their programming assignments in the first year courses, several of the study participants expressed an appreciation for the opportunities they were given for collaborative learning experiences and urged faculty to increase activities in which students had to cooperate rather than compete. Working together toward shared goals increases student involvement with their peers and replaces an atmosphere of competition with one of cooperation. Research shows that many women perform better in a cooperative environment (Brainard & Carlin, 1997; Etzkowitz, 1994; Margolis & Fisher, 2002; Light, 1990; Seymour & Hewitt, 1997; Spertus, 1991; Widnall, 1988). In the Harvard Assessment Seminars (1990), Light speaks specifically to the teaching of the sciences, noting that regardless of workload, students rate courses in the sciences higher when there is less grade competition and recommends building substantive work through creating small student study groups even within large classes, especially in the physical sciences, to promote a community of learners and thereby improve students' academic experience. However, Seymour & Hewitt (1997, P. 300) pointed out that competition for grades in courses tends to undermine trust and the development of friendship in study groups, and for these to work, faculty must rethink the competitive basis of traditional assessment practices.

Paired programming, a method in which two people write a program collaboratively using one computer, is an activity that faculty could use in first year courses to preclude the loss of confidence and isolation that many women experience in computing classes. In paired programming, the "driver" is the person who controls the keyboard and the mouse and enters the program code. The "navigator" sits next to the driver and watches for errors, discusses alternative design approaches, and offers suggestions. The programmers regularly trade roles while pairing. In studies to measure the efficacy of paired vs. solo programming, Werner et al (2004, 2005) found that paired students were more likely to turn in working programs than solo students, and that the programs of paired students correctly implemented more required features than those of solo students. Students working in pairs reported greater confidence and greater enjoyment of the programming process. They were also more likely to complete the course and persist in the computer science major one year following the course in which paired programming was used. Women especially benefited from paired programming, significantly closing the gender gap in persistence in computer science in the classes studied.

Develop more opportunities for faculty and students to interact.

Faculty mentoring of undergraduates can modify the competitive environment of the computer science major, which causes the department to appear uninviting and intimidating to many female students, and also alleviate some students' fears, uncovered in this study, that they lack the aptitude for the major. In addition, the computer science curriculum requires two years of challenging, foundation courses, in which students must learn a new way of thinking and approaching problems, before students have the opportunity to choose computer science electives. Engaging students in research early in the academic program increases their interaction with faculty and inspires in them a passion for the discipline. This is especially true for female students whose motivation in a discipline is closely related to the personal connections that they forge with faculty. First year students in computer science often have little knowledge of the diverse opportunities available in the field. A program of paid research internships for first year students at Dartmouth College resulted in improved retention of undergraduate women in engineering (Muller and Pavone, 1997). External evaluations of the Dartmouth program showed that mentoring provided by faculty through the research internships was often the most valuable aspect of the intern's experience. Students also exhibited an increase in confidence in their academic work and expressed appreciation of their role as part of the team within a lab. The MIT EECS study, which investigated remedies for the imbalance in the undergraduate enrollment of women in Electrical Engineering and Computer Science (1995), noted that student impressions of careers in the major play an important role in students' decision to major in computer science. MIT faculty recommended the EECS department facilitate faculty advertisement of their research projects and student application to these research projects.

Women faculty, especially those who pursue multiple roles as professors, researchers, wives and mothers, show female students that combining an academic career in computer science along with a satisfying family and personal life is achievable. However in many departments of computer science there are few, if any, female faculty. . Women in departments with no female faculty experience more difficulty in believing that their own presence in the major is 'normal.' Moving toward a more equal ratio of male and female faculty and students in the major is the most important factor in helping undergraduate women feel more confident that they belong in the major and can succeed, and in making the participation of

women a taken-for-granted aspect of a discipline (Seymour & Hewitt, 1997). Research conducted by McGrath Cohoon (2000, 2001) on all 23 departments of computer science in the state of Virginia found that several faculty characteristics and practices correlate with women's persistence, including faculty turnover or stability, attitudes, mentoring of students, teaching and the presence of female faculty.

Faculty could also examine the current practice of office hours set aside for students to engage faculty in questions concerning course material and lectures. Many faculty office hours are poorly attended by students. Study participants reported being too intimidated to visit faculty during office hours unless they had a specific question or a substantive issue to discuss. Faculty could pose office hours to students as a less formal opportunity to chat about course topics and actively encourage their students' attendance at office hours. Faculty also could use the advising process to help increase students' confidence. Faculty advisors who establish purposeful relationships with freshmen advisees buttress the department's retention goals, especially for female students.

Aggressively recruit women into the computer science major, creating the opportunity for a critical mass of women in the department.

The CIS department should work with admissions staff to increase the female applicant pool and to identify those qualities and attributes in applicants that increase a student's chance of success in computer science. Research shows that a critical mass of women in a computer science department encourages women's persistence (Etzkowitz, 1991; Margolis & Fisher, 2002; MIT EECS, 1995; Seymour & Hewitt, 1997; Widnall, 1988). Associate Dean of Admissions at the University of Pennsylvania, Bruce Chamberlin, welcomes department involvement and has recommended that the CIS department assist him in developing an applicant profile that indicates applicant characteristics that are key to success in the major. Chamberlin also recommends that the department conduct exit interviews with students who drop out of the major to help determine if the student was a good fit for the major and if there is anything that admissions can do to give applicants information and realistic expectations for the major.

High school computer science teachers could also provide the department with a conduit to girls interested in technology and an opportunity to discuss curricular issues with teachers, heighten teachers' awareness of gender issues which impede girls from enrolling in computer science courses in high school,

and help teachers improve their programming courses. Carnegie Mellon University credits their outreach to high school teachers for substantially increasing their enrollment of women in computer science programs (Blum, 2001; Margolis & Fisher, 2002) and this outreach could yield similar benefits to Penn.

Recommendations for high schools and computer science teachers

Promote the study of computer science by targeting high achieving female math students, and exposing them to and encouraging them in the discipline.

Girls' enthusiasm for computer science could be nurtured by increasing their participation in computer science courses, summer camps, and computer and technology clubs. Through partnering with parents and forging university and corporate alliances, secondary schools could develop programs that would diminish peer pressure against female involvement in computer science, and encourage girls' increased participation.

Parents exert a profound influence on their daughters' self image, self-esteem and confidence in their capabilities. Like the parents of the participants in this study, parents should convey to their daughters that they are capable of achieving in a technology field, and encourage them to take the highest available courses in math, science and computer science to prepare them to succeed in college. High school teachers are second only to parents in exerting influence on girls' assessment of their capabilities to study math, science and technology. Parents and teachers need to partner to ensure that girls are adequately prepared through computer science courses, camps and clubs in high school to successfully pursue computer science in college.

Direct resources to the teaching of computer science by increasing the college prep curricular offerings in computer science and preparing high school teachers for advanced level instruction.

Interest in computer science develops for many students during high school. Schools should offer a rich computer science curriculum to college bound students. Teachers report that few girls in their schools sign up for computer science courses. Girls report that they dislike the passivity of the computer, the narrow focus of programming courses, and the violence, redundancy and tedium of computer games (AAUW, 2000). Clearly the approach to teaching computer science must change to garner a greater

participation of female students. Although girls are drawn to computers for web design and graphics programs, the standards for technology fluency today must go beyond these basic applications and rely on integrating computer science across the curriculum in art, music and literature where girls' interests often lie, as well as in math and science. High schools should target high achieving math and science girls to take AP computer science and develop a rich computer science curriculum that promotes higher level skills, such as the ability to use abstract reasoning, to apply information technology across disciplines to solve problems, to interpret analytically vast amounts of information, to understand the basics of computer programming and to be able to continually adapt to new technologies as they emerge (AAUW, 2000).

The Java Engagement for Teacher Training Program (JETT) provides an excellent starting point for high schools that are interested in expanding their computer science program. A partnership between the Association for Computing Machinery (ACM), the Computer Science Teachers Association and the College Board, JETT provides quality pedagogically oriented workshops and resources in Java for secondary high school computer science teachers hosted by universities. JETT was developed to meet the immediate needs of secondary computer science educators in order to ramp up their knowledge of Java due to the Advanced Placement (AP) language switch from C++ to Java beginning in the 2003-2004 academic year. JETT's broader mission is to facilitate new partnerships between universities, ACM Student Chapters, and the College Board to encourage and support efforts to provide critically needed professional development for high school teachers. The Computing Research Association (CRA) also offers resources to high schools such as Female Involvement in Real Science and Technology (FIRST) which helps schools set up after-school science clubs for girls, The Backyard Project which offers summer technology and engineering camps for high school girls, and numerous mentoring programs that connect girls to professional women in computer science who serve as role models.

Teachers must be vigilant in establishing effective classroom practices that give girls an equal opportunity to boys to contribute in class. Research on teaching and learning has documented "the chilly climate" girls and women may experience in the classroom (AAUW, 1991; Gurer & Camp, 2000; Sadker and Sadker, 1994; Sandler, Silverberg, and Hall, 1996; Tobias, 1990), characterized by unequal attention from teachers in elementary school through college, and persistent discouragement and devaluation. The environment of the computer science classroom welcomes girls by giving them leadership roles in class,

setting high standards for them in the classroom, and providing collaborative rather than competitive activities and assignments.

The conclusions drawn from this study demonstrate that it is possible for parents and high schools to interest girls in studying computer science, and there is much that university schools and departments of computer science can do to attract women into the major and to support their persistence. In addition, many of the recommendations derived from this research study support the persistence of men as well as women in computer science majors in college. Male students also benefit from a richer pre-college curriculum in computer science, entry courses into the major which match students' prior experience in the discipline, effective academic support, increased interaction with faculty, a more cooperative learning environment, and a welcoming atmosphere in which to study.

Many pressing reasons call for the encouragement of women and girls to study computer science. Technology jobs command excellent pay and the number of jobs requiring technology and engineering skills in the U.S. labor force is growing at 5 percent per year, far outstripping other fields. At the same time, the National Science Board warned in 2004 of a troubling decline in the number of U.S. citizens who are training to become scientists and engineers, compounded by the decline in the availability of people from other countries who have science and engineering training, either because of limits to entry imposed by U.S. national security restrictions or because of intense global competition for people with these skills. In addition, the technology field currently is missing almost half of the population's input in solving diverse problems for business, medicine, the military, the social sciences and the arts. Computer science is an exciting, rewarding and worthwhile endeavor. Robots are being developed to perform dangerous tasks for the military, computer models are being designed to map chromosomes for the human genome project, computer programs optimize airlines' safety standards, smart wheelchairs empower handicapped people, and new graphical interfaces make computers easier for novices to use. These challenging activities are current research projects at the University of Pennsylvania and they could excite women as well as men. It is in the best interest of all constituents, including secondary schools, colleges and universities, to facilitate women's full participation in this discipline.

REFERENCES

American Association of University Women. (1991). *Shortchanging Girls, Shortchanging America*. American Association of University Women Educational Foundation: Washington DC.

American Association of University Women. (1992). *How Schools Shortchange Girls*. American Association of University Women Educational Foundation: Washington DC.

American Association of University Women. (1998). *Gender Gaps: Where Schools Still Fail our Children.* American Association of University Women Educational Foundation: Washington DC.

American Association of University Women. (2000). *Tech Savvy: Educating Girls in the New Computer Age.* American Association of University Women Educational Foundation: Washington DC.

Angelo, T. (1996, December) Seven Shifts and Seven Levers: Developing More Productive Learning Communities." National Teaching and Learning Forum. 6 (1).

Astin, A. (1992). Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences. Final Report. University of California at Los Angeles. Higher Education Research Institute. (ED362404)

Astin, A. (1993). *What Matters in College: Four Critical Years Revisited*. .San Francisco: Jossey-Bass.

Baron-Cohen, S. (2003). *The Essential Difference: The Truth about the Male & Female Brain.* New York: Basic Books, Inc.

Belenky, M. F., Clinchy, B., Goldberger, N., & Tarule, J. (1986). *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York: Basic Books, Inc.

Bell, A. & Spencer, S. (2002). The Effect of Stereotype Threat on Women's Performance on the Fundamentals of Engineering Exam*." Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition.*

Bernstein, D. R. (1997). Computing, Diversity and the Community: Fostering the Computing Culture. *28th SIGCSE Conference*, San Jose, CA. Retrieved March, 2005, from http://www.kean.edu/~dbernste/pcsacm.html

Blum, L. (2001, January 27). Women in Computer Science: The Carnegie Mellon Experience Retrieved April, 2005, from http://www.2.cs.cmu.edu/~lblum/PAPERS/women_in_computer_science.pdf

Blum, L. (2001, October 2,).Transforming the Culture of Computer Science. Retrieved April, 2005, from http://www-2.cs.cmu.edu/~lblum/PAPERS/TransformingTheCulture.pdf

Blum, L & Frieze, C. (2005). The Evolving Culture of Computer Science. Retrieved May, 2005, from http://www-2.cs.cmu.edu/~lblum/PAPERS/TheEvolvingCSCulture.pdf

Brainard, S. & Carlin, L. (1997). A Longitudinal Study of Undergraduate Women in Engineering and Science. *ASEE/IEEE Frontiers in Education Conference*. Pittsburgh.

Cabrera, A.F., Castaneda, M., N., A., & Hengstler, D. (1992). The Convergence Between Two Theories of College Persistence, *Journal of Higher Education, 63*, 143-164.

Camp, T. (1997, October). The Incredible Shrinking Pipeline. *Communications of the Association of Computing Machinery 40* (10) 103-110.

Camp, T., K. Miller, & Davies, V. (2000). The Incredible Shrinking Pipeline Unlikely to Reverse. Retrieved April 2005, from http://www.mills.edu/fs_home/tcamp/new-study.html

Cohoon, J. McGrath. (1999). Departmental Differences Can Point the Way to Improving Female Retention in Computer Science. *SIGCSE Bulletin* 31 (1), (pp. 198-202).

Cohoon, J. McGrath. (2001). Toward Improving Female Retention in Computer Science. *Communications of the ACM. 44* (5), (pp. 108-114).

CRA Taulbee Survey, (2002). Retrieved May, 2005, from http://www.cra.org/statistics/

Cuny, J. & Aspray, W. (2000). Recruitment and Retention of Women Graduate Students in Computer Science and Engineering. *CRA: Committee on the Status of Women in Computing Research. Workshop Report.* June 20 and 21.

Davis, C, A. Ginorio, C. Hollinshead, B. Lazarus, P. Rayman, & Associates, (1996). *The Equity Equation: Fostering the Advancement of Women in Science, Math and Engineering. S*an Francisco: Jossey-Bass.

Etzkowitz, H., Kemelgor, C. & Uzzi, B. (2000). *Athena Unbound: The Advancement of Women in Science and Technology*. London: Cambridge University Press.

Etzkowitz, H. (1994). Who Will Do Science? In *Educating the Next Generation*. W. Pearson and I. Fechter, (Eds.) Baltimore: John Hopkins University Press.

Emerson, R., Fretz, R. & Shaw, L. (1995). *Writing Ethnographic Field Notes.* Chicago: University of Chicago Press.

Frenkel, K. (1990, November). *Becoming a Computer Scientist*. In A Report by the ACM Committee on the Status of Women in Computing Science. 33 (11), (pp. 33-46).

Freire, Paulo. (1970). *Pedagogy of the Oppressed*. New York: The Seabury Press.

Frieze, Carol, & Lenore Blum. *Building an Effective Computer Science Student Organization: The Carnegie Mellon Women@SCS Action Plan.* Retrieved April, 2005, from http://www-2.cs.cmu.edu/~cfri9eze/paper.html

Hammersley, Martyn & Paul Atkinson. (1995). *Ethnography: Principles in Practice*. (2nd ed.) New York: Routledge.

Gilligan, C. (1993). *In a Different Voice*. Cambridge, MA: Harvard University Press.

Furger, R. (1998). *Does Jane Compute? Preserving Our Daughters' Place in the Cyber Revolution*. New York: Warner Books.

Gokhale, A. (1995). Collaborative Learning Enhances Critical Thinking. *Journal of Technology Education. 7*, (1).

Goodman, I., Cunningham, C., Lachapelle, C., Thompson, M., Bittinger, K., Brennan, R. & Delici., M. A Comprehensive Evaluation of Women in Engineering Programs. (2002). *Final Report of the Women's Experiences in College Engineering (WECE) Project.*(National Science Foundation #9725521, Alfred P. Sloan Foundation #96-10-16) Retrieved May, 2005, from http://www.grginc.com/reportsandpubs.html

Gurer, D., & T. Camp. (2001). Investigating the Incredible Shrinking Pipeline for Women in Computer Science. (*Final Report-NSF Project 9812016).*

Jeffries, R., S. Kiesler, J. Goetz, & L. Sproul. *Systers: Contradictions in Community*. Retrieved May, 2005, from http://www.anitaborg.org/projects/systers/contradictionsincommunity.pdf

Kluge, P. (1993). *Alma Mater*. New York: Addison-Wesley Publishing Company.

Kuh, G. Schuh, D., Whitt, J., & Associates, E&J. (1991). *Involving Colleges: Successful Approaches to Fostering Student Learning Outside the Classroom.* San Francisco: Jossey-Bass.

Lazerson, M. & Wagener, U. 1999. Teaching and Learning the Unfamiliar. *Change*. 31, 1.

Leeper, R., & Silver J. (1982). Predicting success in a first year programming course. *Thirteenth SIGCSE Technical Symposium on Computer Science Education*, Indianapolis, Indiana.

Levenson, N. (1990). *Educational Pipeline Issues for Women*. Retrieved March, 2005, from http://www.mills.edu/ACAD_INFO/MCS/SPERTUS/gender/pipeline/html

Light, Richard. (1992). *The Harvard Assessment Seminars*. Cambridge, MA: Harvard University Press.

Margolis, J., Fisher, A., & Miller, F. (2000). Caring about Connections: Gender and computing. *Technology and Society* 18 (4), 13-20.

Margolis, J. & Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: The MIT Press.

Maxwell, J. (1996). *Qualitative Research Design: An Interactive Approach*. London: Sage Publications.

McDowell, C., Werner, L., Bullock, H., & Fernald, J. (2002). The Effects of Pair Programming on Performance in an Introductory Programming Course. *33rd SIGSE Technical Symposium on Computer Science Education.* Northern Kentucky: ACM Press.

McDowell, C., Hanks, B., & Werner, L. (2003). Experimenting with Pair Programming in the Classroom. (2003).
Proceedings on the Eighth Annual Conference on Innovation and Technology in Computer Science Education. (IT1CSE). June 30—July 2, 2003.

McPherson, M., & Schapiro, M. (1997). *Financing Undergraduate Education: Designing National Policies.* National Center for Postsecondary Improvement: Stanford, CA.

Miller, J. Baker. (1986). *Toward a New Psychology of Women*. (2nd ed.)Boston: Beacon Press.

Miller, S. (1995). *An American Imperative: Accelerating Minority Educational Advancement.* New Haven, CT: Yale University Press.

MIT EECS Committee on Women Undergraduate Enrollment. (1995). *Women Undergraduate Enrollment in Electrical Engineering and Computer Science at MIT.* Cambridge, MA: Massachusetts Institute of Technology Retrieved April, 2005, from http://www-eecs.mit.edu/AY94-95/announcements/13.html.

Muller, C. & Pavone, M. (1997). *Retaining Undergraduate Women in Science, Math and Engineering: A Model Program.* IEEE 1997 Frontiers in Education Conference.

National Science Foundation (1999). Division of Science Resources Statistics, SESTAT (Science and Engineers Statistical Data System).

National Science Foundation. (1996). Women, Minorities, and Persons with Disabilities In Science and Engineering. Washington D.C.

National Science Foundation. (1998). Women, Minorities, and Persons with Disabilities In Science and Engineering. Washington D.C.

National Science Foundation. (2000). Women, Minorities, and Persons with Disabilities In Science and Engineering. Washington D.C.

National Science Foundation. (2002). Women, Minorities, and Persons with Disabilities In Science and Engineering. Washington D.C.

National Science Foundation. (2004). Women, Minorities, and Persons with Disabilities In Science and Engineering. Washington D.C.

Pascarella, E.T., & P. Terenzini. (1998). Studying College Students in the 21st Century: Meeting New Challenges. 21 (2), 151-165.

Pascarella, E.T., & P. Terenzini. (1991). How College Affects Students. San Francisco: Jossey-Bass.

Pearl, A., Pollack, M., Riskin, E., Thomas, B., Wolf, E., & Wu, A. (1990). Becoming a Computer Scientist. *A Report by the ACM Committee on the Status of Women in Computing Science*. November 33 (11), (pp. 47-58).

Pipher, M. (1994). *Reviving Ophelia: Saving the Selves of Adolescent Girls.* New York: Ballantine Books.

Rosser, S., Ed. (1995). *Teaching the Majority. Breaking the Gender Barrier in Science, Mathematics, and Engineering.* New York: Teacher's College Press.

Sadker, M. & Sadker, D. (1994). *Failing at Fairness: How Our Schools Cheat Girls*. New York: Touchstone Books.

Sax, L. ((1996). The Dynamics of 'Tokenism: How College Students are Affected by the Proportion of Women in Their Major. *Research in Higher Education. 37* (4), 389-425.

Sax, L. (1994). Mathematical Self-Concept: How College Reinforces the Gender Gap. *Research in Higher Education*. 35, (2), 141-167.

Seymour, E., & Hewitt, N. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, Colorado: Westview Press.

Spertus, E. (1991). Why *are There So Few Female Computer Scientists?* (AI Technical Report 1315). Cambridge, MA:, Massachusetts Institute of Technology, Artificial Intelligence Lab.

Steele, C. M. (1997). A Threat in the Air: How Stereotypes Shape Intellectual Performance. *American Psychologist*. 52 (6), 613-629.

Strenta, A., Elliott, R., Adair, R., Matier, M., & Scott. J. (1994). Choosing and Leaving Science in Highly Selective Institutions. *Research in Higher Education*. 35 (5), 13-547.

Study on the Status of Women Faculty in Science at MIT. (1999). *The MIT Faculty Newsletter.* XI (4). Retrieved April, 2005, from http://web.mit.edu/fnl/women/women.html

Tobias, S. (1990). *They're Not Dumb, They're Different: Stalking the Second Tier*. Tucson, Arizona: Research Corp.

Triesman U. (1992). Studying Students Studying Calculus: A Look at the Lives of Minority Mathematics Students in College. *The College Mathematics Journal. 23* (5) 362-372.

Triesman, U., Fullilove, R., & Lang, E. (1990). Mathematics Achievement Among African American Undergraduates at the University of California, Berkeley: An Evaluation of The Mathematics Workshop Program." *Journal of Negro Education*. 59, (3), 463-476.

Tinto, V. (1998). *Colleges as Communities: Taking Research on Student Persistence Seriously.* 121 (2), 167-177.

Tinto, V. (1998). *Classrooms as Communities: Exploring the Educational Character of Student Persistence. 68*, 599-623.

Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition.* (2nd ed.). Chicago: The University of Chicago Press.

Tinto, V., Goodsell-Love, & Russo, P. (1995). *Building Learning Communities for New College Students.* National Center on Postsecondary Teaching, Learning, and Assessment.

Tobias, Shiela. (1990). *They're Not Dumb, They're Different. Stalking the Second Tier*. Tucson, Arizona: Research Corporation.

Valian, Virginia. (1998). *Why So Slow? The Advancement of Women*. Cambridge, MA: Massachusetts Institute of Technology Press.

Vegso, J. (2005) Interest in CS as a Major Drops Among Incoming Freshmen. *Computing Research News.* May 17 (3).

Wagener, U. (1992*). Environments* of Support. Washington, D.C.: American Council on Education. (ERIC Documentation Reproduction Service No. Ed 363 249).

Werner, L., Hanks, B., & McDowell, C. (2005). Female Computer Science Students Who Pair Program Persist. Retrieved May, 2005, from www.cse.uscs.edu/~charlie/pubs/jeric2005.pdf

Werner, L., Hanks, B., McDowell, C., Bullock, H., & Fernald, J. (2005, March). Want to Increase Retention of Your Female Students? *Computing Research News*. 17 (2). Retrieved April, 2005, from http://www.cra.org/CRN/articles/march05/werner.html

Werner, L., Bullock, H., McDowell, C., & Fernald, J. (2004, October). *Retaining Women in Computer Science: The Impact of Paired Programming Project Update*. ITWF/ITR Workforce PIs Meeting, October. Retrieved April, 2005, from http://www.cse.ucsc.edu/~charlie/pubs/nsf_summary_nov_2004.pdf

Widnall, Shiela E. (1988, September 30) AAAS Presidential Lecture: Voices from the Pipeline. *Science*. New Series. 241 (4874), 1740-1745.

Yin, Robert K. (2003). *Case Study Research: Design and Methods*. (3rd ed.) London: Sage Publications.