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Barriers to women in undergraduate computer science: The effects of the computer environment on the success and continuance of female students

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BARRIERS TO WOMEN IN UNDERGRADUATE COMPUTER SCIENCE: THE EFFECTS OF THE COMPUTER ENVIRONMENT ON THE SUCCESS AND CONTINUANCE OF FEMALE STUDENTS

by

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A DISSERTATION

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Dr. Chet A. Bowers

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This study examined female undergraduate computer science students' experiences at a public university in the northwestern United States during 1980-1987. Its objective was to identify barriers that contributed to the underrepresentation of women in this program. My experience, as an undergraduate and graduate computer science student at this university, made me aware of the formidable barriers to women's success and continuance in this academic field. To uncover these barriers, three separate sources of information were analyzed: (a) interviews with 22 women, (b) 12,333 individual enrollment and achievement records in computer science courses, and (c) the pertinent literature from relevant fields--computer science, mathematics, engineering, and science.

An amalgamation of feminist methodology and grounded theory guided the design of the study and the analysis of the data.

The analysis of the interviews and the literature brought to light multiple barriers. These barriers were organized into two major categories: (a) the barriers resulting from the overrepresentation of men and (b) those stemming from women's direct interaction with the computer science environment.

The analysis of the enrollment and achievement data revealed that women received proportionately more A's than men in five of the eight required computer science courses and proportionately more satisfactory grades--A's and B's, needed for continuance in the program--in seven of them. However, despite their academic success, women dropped out of the program proportionately more often than men. They comprised 30.68% of student enrollment in the beginning required computer science course (CIS 201) and 23.22% in the last required course (CIS 423). The ratio women:men changed from 1:3.26 to 1:4.31.

The results of this study suggest that the underrepresentation of women in undergraduate computer science is not related to any deficiency innate in them. Probably, it originates in enculturing and socializing forces that cause women and men to perceive women less able than men to study computer science. Most likely, it is perpetuated by the isolating, foreign, and alienating nature of the computer science environment itself. The women who succeed do so at great personal cost and sacrifice.

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DEDICATION

To Sandoval

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CHAPTER I

INTRODUCTION

Purpose of the Study

The purpose of the present study was to identify barriers female undergraduate computer science students faced while involved in this academic field. Further, the study focused on formulating recommendations for an undergraduate computer science environment that would minimize the barriers found so as to attract and retain female students.

Background of the Study

Women are underrepresented in the areas of computer science that permit the creation and exploration of new ideas, allow more individual autonomy, and pay larger salaries. Access to these areas of the profession is greatly facilitated by the possession of undergraduate and/or graduate degrees in computer science. These necessary degrees are, in turn, primarily dependent on the consistent choice of mathematics, science and computer science courses throughout high school. During the first years of formal education, female and male students are "required" to take mathematics and science courses and most studies indicate that they perform equally well (Armstrong, 1985; Fennema & Sherman, 1977, 1978; Linn & Petersen, 1986; Meece, Parsons, Kaczala, Goff, & Futterman, 1982; Sherman, 1980a, 1980b, 1982; Stage & Karplus, 1981; Tomizuka & Tobias, 1981). However, when students are permitted to "choose" in the continuing process of acquiring their education, many girls enroll in courses that impair or seriously curtail their ability to enter undergraduate and/or graduate programs that lead into the more creative areas of computer science.

My own personal experience in the field bears this out. I chose to major in computer science when I entered the University of Oregon (the University) as an undergraduate student. The proportion of students in the beginning classes for majors indicated that I was a member of the minority--more men chose this major than did women. The proportion of women to men decreased progressively in each undergraduate computer science class in which I enrolled until women comprised a mere 21% of my major's graduating class. The absence of a representative number of women is, unfortunately, not unique either to my alma mater or to the study of computer science: It pervades the field of mathematics and other areas of science as well.

I spent considerable time talking with discouraged computer science students in general. (I was an older female student and, therefore, may have been viewed as a safe person in whom to confide.) Students' musings to me often were, "I have always received A's in school; I study very hard; I believe that I understand the concept; but something must be wrong with me." Frequently, these students dropped out after the first midterm to avoid the failing grade that they believed certainly would appear on their transcript. Even though they may have received a higher grade on an examination than I had, they became convinced that they were not intelligent enough to continue in this field. Often these students were ignoring their other classes and concentrating most of their time on a computer science class from which they were receiving no positive feedback for their efforts. A class average of 30% on a midterm or final examination was common and did little to reinforce their labors. More often than not, the students undergoing the experiences described above were women.

With time, I became aware that women's alienation from computer science could not be accounted for on the basis of inability but that other, albeit more profound and/or less understood, reasons induced it. Gradually, I began to formulate questions about what was happening: Why do so few women "choose" a computer science major? Why do they "choose" to leave this program after they have entered it? The search for answers was born.

The very nature of the computing world seems to me to be at least a partial answer to these questions. The study of computer science has earned a reputation among students and faculty alike of being a "killer" at both the undergraduate and graduate levels. This reputation is well founded. I often wondered if I would survive. Though computer science can be onerous conceptually, the "killer" label is derived from other aspects of the educative process. This can be illustrated by the need to work day and night for several days in a row in order to complete assignments or get through the virtually impossible task of accessing complicated theories that are walled behind obscure and abstract codes.

Personal experience and published reports suggest that the label "alien" rather than "killer" more accurately could be applied to this field of study. A foreign climate permeates computer science departments in general (Dubrovsky, Kiesler, Sproull, & Zubrow, 1986; The Hacker Papers, 1980; Kidder, 1981; Kiesler, Sproull, & Eccles, 1983, 1985; Levy, 1984; Sproull, Kiesler, & Zubrow, 1984). My experience was not an exception in this regard. One was required to work in an unaccustomed physical environment. The social climate of the classrooms, hallways, and computer laboratories was strange: the language spoken by the members of the "clan" was foreign; the language and content of textbooks, user manuals, assignments, examinations, on-line help facilities, and the like were opaque; and departmental procedures and requirements often lacked precision and appeared to be arbitrary. All of this produced a sense of alienation that was overwhelming to many students, the majority of whom were women who subsequently withdrew from computer science. Sometimes, the brightest women seemed to be the first to leave the program.

Some investigators have explored briefly the factors that contribute to this sense of alienation or estrangement that proves fatal to so many women attempting to study computer science. More substantial research efforts have been conducted examining a similar phenomenon as it is displayed in women's contact with the disciplines of mathematics, engineering, and science. Although not directly related to the principal focus of the present effort, the latter research was helpful in filling the gaps and in providing bridges to reasonable deductions. The reports of these endeavors can be divided into three main emphases: environmental, cognitive, and psychological.

The studies dealing with environmental factors have explored the influences of school, home, and society on women's common choice not to study mathematics, engineering, science, or computer science. They have examined expectations, encouragement, and support from students' significant others (Casserly, 1975; Casserly & Rock, 1985; Chipman & Wilson, 1985; Cooper, 1979; Ernest, 1976; Fennema

& Koehler, 1983; Fox, Tobin, & Brody, 1979; Hall, 1982; Houser & Garvey, 1985; Kelly, 1981; Luchins & Luchins, 1981; Parsons, Adler, & Kaczala, 1982; Sadker & Sadker, 1985; Sherman, 1983; Stallings, 1985; Thomas, 1986). They also have dealt with the lack of unconventional role models that condition the perceptions of men and women regarding their "appropriate" role in society (Matthews, 1983; Tidball, 1980, 1985, 1986; Tobin & Fox, 1980; Van Fossen, 1977; Young & Young, 1974). They have suggested that this lack is reinforced by the sex-biased content, language, illustrations, metaphors, and exercises in textbooks and other instructional materials (Gershuny, 1977; Giacomini, Rozee-Koker, & Pepitone-Arreola-Rockwell, 1986; Nilsen, 1977; Sadker & Sadker, 1979; Scott, 1981; Scott & Schau, 1985; U'Ren, 1971). Still others have examined interactions in the classroom to determine if women were enjoying a facilitatory instructional environment (Becker, 1981; Boersma, Gay, Jones, Morrison, & Remick, 1981; Brophy & Good, 1974; Brophy, 1985; Kahle & Lakes, 1983; Lindow, Marrett, & Wilkinson, 1985; Rosenfeld & Jarrard, 1986; Webb, 1984a). A few investigators (Fennema, Wolleat, Pedro, & Becker, 1981; Linn & Petersen, 1986; Parsons et al., 1985) have intervened in the classroom using programs that modified some of the above parameters in the school environment and have succeeded in increasing female students' participation and achievement in mathematics, engineering, and science. As a whole, this research convincingly argues that women's near invisibility in the fields of mathematics, engineering,science, and computer science probably is not rooted in genetic differences, but in cultural and societal norms.

The studies dealing with cognitive factors have focused on finding the differences in cognitive abilities between women and men that would explain women's underrepresentation in mathematics and related sciences (Chipman & Wilson, 1985; Connor & Serbin, 1985; Halpern, 1986; Hyde, 1981; Linn & Petersen, 1986; McClurg, 1985; Nash, 1975; Sherman, 1981). The cognitive parameters examined by these studies were intelligence and the abilities related to verbal, visual-spatial, and quantitative aptitudes. A number of criticisms may be levelled at this research: (a) These studies varied in their treatment of definitions of critical terms, such as "intelligence;" (b) they differed in the set(s) of skills required to demonstrate accurately that one possesses a particular ability; (c) the testing and measuring instruments utilized lacked neutrality and were used in environments often perceived as threatening by women; (d) there was a general unaccounting for external factors, such as ethnic background, socio-economic status, and family environment; and (e) the results reported were dissonant. All of these factors indicate that future studies need to be more carefully designed and implemented.

To date, the efforts to demonstrate cognitive sex differences largely remain unconvincing.

In the present study I have included a review of the studies examining only those cognitive skills that previous researchers have shown to be needed in order to successfully study computer science, namely, identification of language features, design skills, problem solving skills, reading and comprehension of programs, and debugging.

Finally, the psychological factors shown by investigators to influence women to veer away from the fields of mathematics, engineering, science, and computer science were examined. Here I have grouped the studies centering on the characteristics of students and their view of themselves and of their environment (Gitelson, Petersen, & Tobin-Richards, 1982; Mason & Kahle, 1988; Wahl & Besag, 1986), as well as the difference of attitude between women and men in relation to these sciences (Berryman, 1983; Brush, 1980, 1985; Chipman & Thomas, 1984; Chipman & Wilson, 1985; Meece et al., 1982; Pedro, Wolleat, Fennema & Becker, 1981; Sells, 1976; Thomas, 1984, 1986; Tsai & Walberg, 1983). These studies parallel and reinforce the environmental group of studies: Their findings suggest that the different ways in which female and male students view these sciences also stem from the environment surrounding students in and out of school.

Study Design

Two basic questions guided my investigation: (a) What kind of experiences did the women have while studying undergraduate computer science? and (b) What form would a computer science program have that would attract and retain women in this field? The first question led to the identification of barriers women face in computer science and the second to the exploration of possible solutions to these problems. I have used four sources of data to answer these questions: (a) Interviews with women who had studied computer science at the University during the period 1980-1987; (b) my own experience as an undergraduate and graduate student at the University; (c) enrollment and achievement data during the same time period at the University; and (d) previous research.

The Interviews

Twenty-two women who, at the time of the interviews, lived in Eugene, Oregon, were selected because they were, or had been, involved in the study of computer science at the University. Their ages ranged from 20 to 45 years. The interviews were conducted in one-on-one meetings and telephone conversations over a period of several months. Our discussions were essentially unstructured. We discussed the following components of the computing milieu and their effects on the interviewees: (a) the language, structure, and content of textbooks, training and reference materials; (b) classroom instruction; (c) evaluation instruments and procedures; (d) the nature of operating system commands; (e) the physical components of the computer and design aspects of the software; (f) the physical environment of the computer laboratory; (g) the social ambience of classrooms, computer laboratories and other gathering places; (h) characteristics of computer science people and interactions with them; (i) departmental entrance requirements and other departmental policies; (j) beliefs these women held due to earlier socialization regarding computing and related activities; and (k) feelings concerning their experiences during their undergraduate study of computer science. This framework, rather than working to confine our dialogue, expanded it to include as many aspects of the computing environment as possible.

The Enrollment and Achievement Data

The data set included 12,333 individual enrollment and achievement student records[1]. These records contained student enrollment from 1980-1987 in all of the computer science courses included in an undergraduate computer science major. Each record contained the students' social security number, sex, course number, term and year of enrollment, grade, and professor's sex.

Significance of the Study

Educational administrators, computer science teachers, women contemplating the study of this discipline, and the field itself could benefit from the results of this investigation.

The description of the women's experiences during their study of computer science could raise administrators' level of awareness by providing them with specific actions they could implement in their departments to facilitate women's access to and retention in the undergraduate study of computer science.

Teachers of computer science could be made aware of the barriers confronting women entering or continuing in this field. These teachers could have a powerful influence in minimizing attrition as has been demonstrated by several successful intervention studies (Fennema, 1984; Stasz, Shalvenson, & Stasz, 1985).

Women who wish to major in computer science could benefit from having access to the experiences of other women who have similar interests. By seeing how these other women faced the barriers encountered, by witnessing the expression of their frustrations, failures, and successes, they would be better prepared themselves when facing similar barriers. This knowledge could help provide the support and encouragement necessary to continue the pursuit of their goal. Finally, these articulated experiences could function as bridges between women and the "alien" environment of computer science.

If, as a consequence of the results of my investigation, more women are able to persist in their study of computer science, this field of human endeavor also would benefit. Winograd and Flores (1986), have expressed the conviction that we must rethink the basic premises upon which this science is built if new advancements are to be possible. The traditional views of reality informing the present conceptualizations are being pushed to their limit. Could it be that one of the reasons for the lack of progress evidenced in natural language processing, intelligent tutoring systems, artificial intelligence, and parallel processing is the fact that there is predominantly one view of reality informing the language and concepts of computer science, namely the male view? A learning environment where creativity is fostered and alternative problem-solving strategies are encouraged, potentially could supply alternative conceptualizations.

From its inception, the computer movement has assigned women peripheral contact with the computer as mechanical users who typically are denied entrance into the workings of the machine and its potential to influence every facet of modern life. That women can and do use computers is of less consequence than their ingress and permanence in computer science. Women's contributions to other scientific fields suggest the necessity of their presence in this one-sided field at the level of creative endeavor--namely, the designing of the machines and the systems that operate them, the creation of software, and involvement in the basic research. As Josefowitz (1983) remarked, "We know . . . that heterogeneity promotes creativity" (p. 194).

Review of the Literature

The review of the literature, narrows the factors discussed above to the environmental, cognitive, and psychological factors hypothesized to influence women's attraction to and persistence in computer science. Studies that have examined these factors at the elementary, middle, secondary, and undergraduate levels are reviewed. Women's descriptions of their experiences as computer science undergraduates, graduates, and professionals complete Chapter II.

Although fragmented and with gaps, suggesting the need for more research, the picture that emerges from the review of the literature is rather clear. In the beginning, girls show as much interest in computers as do boys, but soon their interest wanes. It continues to decrease during middle and high school. By the time girls become women and are ready for college, only 1% to 2% of them choose a computer science major. The factors that engender this paucity clearly are environmental--external, outside of the control of women. Some of these factors continue to operate in the undergraduate, graduate, and professional levels to reduce women to near invisibility as they ascend the academic or professional ladder.

Methodology

Chapter III details the theoretical underpinnings upon which the present effort was constructed--feminist methodology and grounded theory. These methods are especially suited to the development of new theories. They were adopted because the area I decided to investigate--undergraduate computer science female students' experiences--is new. As far as I was able to ascertain, the literature contains no comprehensive account of women's experiences at this level. In addition, the second aim of this research--the design of a computer science program to attract and retain women--is particularly appropriate to feminist methodology. This methodology concentrates on defining situations in which women are underrepresented or discriminated against. Its intent is to accurately define the existing scenario in order to uncover the barriers that deter women from equal representation with men in life and then to devise an equitable scenario and the ways to achieve it. Thus, feminist methodology fitted nicely my stated goals.

Female Undergraduates' Experiences While Studying Computer Science

Chapter IV presents female undergraduate computer science students' experiences as recounted in the interviews. Following Cynthia Cockburn's (1988) approach, "I have simply used the best and clearest expressions of the range of ideas that came through the interviews as a whole" (p. 171). It would be misleading to have added them up and 'say 20 women thought this, 12 thought that.' More significant than statistics was the field of issues with which these women were concerned and the tensions that existed between the different meanings they ascribed to them. While dry statistics might identify the existence of the barriers these women faced, they could not explain how these barriers operated in practice. The recounting of these women's experiences could (Lloyd & Newell, 1985).

Discussion and Recommendations

Chapter V discusses the barriers that emerged from the analysis of the four sources of data and explores ways to minimize them. These barriers are examined in conjunction with those previously identified in mathematics and other sciences. The study concludes with suggestions to render the program of undergraduate computer science more attractive to women.

Notes

[1]Information for students whose social security numbers began with 999- was not included in the data set.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Five main questions guided my search of the literature dealing with the experiences of women while studying undergraduate computer science: (a) To what extent are women involved in the study of computer science?[1] (b) How are the involved women relating to this pursuit? (c) Are they able to succeed at this pursuit? (d) Do they like it? (e) If they do not continue, when does this happen and what are the reasons?

In keeping with the goals of this research--to relate accurately women's experiences in the study of computer science at the undergraduate level and to envision a program of study in which their success and continuance are facilitated--and because so little work has focused on the study of undergraduate computer science education, I decided to include in this review a description of female students' involvement at the elementary, middle, and high school levels. In doing so, I extended the boundaries of this chapter closer to areas where the foundations for success or failure in undergraduate computer science were laid. The review continues with a detailed description of the few studies relating to female students' experiences at the undergraduate level and concludes with studies depicting women's experiences in computer science at the graduate and professional levels. The latter studies are included because they shed light on the future prospects of women who, although successful at the undergraduate level, continue to face many of the same problems and difficulties that confronted the undergraduate women.

The discussion includes the studies examining the following factors influencing women's experiences in the study of computer science: (a) environmental: participation in and availability of experiences using the computer, early socialization, presence of role models and mentors, parents' and teachers' encouragement and expectations, peers' influence, high school mathematics and science courses, computerese, computer, documentation, masculine identity, and association with mathematics and science; (b) cognitive: high school and college achievement and computing abilities, including identification of language features, design skills (usage of templates and procedural techniques for organizing language features into a program), problem solving skills (problem analysis and understanding), reading and comprehension of programs, and debugging; and (c) psychological: self-efficacy, computer anxiety, and feelings and interest toward computers; beliefs that the computer is useful, that it is equally appropriate for women's and men's usage, that it is difficult, and that those who study it must possess mathematical excellence; and plans to pursue the learning of computer science.

The branches of research that I explored in trying to answer the above questions were cross-disciplinary. From diverse sources, I have created an interdisciplinary portrait of women as they move on from their early scholastic endeavors to their involvement in undergraduate computer science and beyond.

A considerable body of research exists that explores the area of computer literacy. This review does not report on these efforts because of two reasons. First, they examine students as users of software. Second, they do not explore the role of students as creators of software. This, of course, is the role held by computer scientists.

Some of the studies reviewed are part of a larger body of research focusing on sex differences. I hesitated to use this research because: (a) much of it views women in relation to men--women are described as having characteristics that are less than or more than men's; (b) it presents a skewed picture of women and men because it does not include the many unpublished studies that found little or no difference between them;[2] and (c) it generally follows a biological deterministic argument while ignoring equally important social and cultural factors.

Nevertheless, I have included in the discussion those studies from which I was able to glean information about women's experiences while studying computer science.

Other appropriate studies reviewed in this chapter are part of the body of research created in response to students' inundation of computer science departments during the early 1980s. At that time these departments did not have sufficient personnel, hardware, or software to handle the influx of students. Consequently, the faculty wished to identify as quickly as possible those students who were most likely to succeed in their pursuit of a degree in computer science. This research led to the depiction of the "successful" student. It, therefore, informs our discussion of women's experiences in this field and is included.

Feminist research would seem to be most appropriate to the aim of the present study and to deserve a place in this review. It has encompassed several disciplines and has sought to "question previous research on sex differences in educational abilities and outcomes that have prevailed in the discipline, the research, and its translation into school practice" (DuBois, Kelly, Kennedy, Korsmeyer, & Robinson, 1987, p. 25). Already it has created a remarkable body of knowledge that gives women a voice and women's interpretation of reality a solid place in the literature. Unfortunately, very little of this research explores women's experiences in the undergraduate study of computer science.

It, therefore, largely remains outside the scope of this review. However, bits of information provided by female undergraduates, graduate students, research staff members, professors, and computer professionals in the United States and abroad are quilted together from this body of literature to form as complete a picture as possible of women's interactions with university computer science study.

Elementary and Middle School Female Students' Experiences

Environmental

The foundation for success or failure in the undergraduate study of computer science apparently is laid early in students' schooling. Studies investigating students' experiences with computers during the elementary and middle school levels show that, even during these early years, although they achieve equally, girls participate less than boys in computer classes and/or computer-related activities in the classroom (Lockheed, 1985a, 1985b; Sanders, 1984). This difference widens as the sophistication of the programming courses increases--female student enrollment, reported to be less than 36% in optional beginning programming classes, dropped to less than 14% in advanced programming classes (Becker & Sterling, 1987; Dalbey & Linn, 1986; Linn, 1985a; Linn & Dalbey, 1985; Miura, 1986; Miura & Hess, 1984). Moreover, only 8% to 22%

of the users of the schools' computing facilities during free-time were female students (Becker & Sterling, 1987; Breakwell & Fife-Schaw, 1987; Lockheed, 1985b; Persell & Cookson, 1987; Turkle, 1984). In addition, investigators related that very few girls were attracted to or played computer games (Fetler, 1985; Lin & Lepper, 1987)--a method of acquiring familiarity with the computer frequently used by many boys. Furthermore, other studies determined that fewer girls than boys had access to a computer at home (Chen, 1986; Fetler, 1985; Miura, 1986; Miura & Hess, 1984) and girls reported spending significantly less time using the home-computer (Miura, 1986).

Few studies, investigating this educational level, have examined female students' significant others' expectations and/or encouragement of girls' involvement with computers. However, the existing reports present a consistent pattern. Significant others--parents, teachers, and peers--give little or no encouragement to girls to involve themselves with the study of computers (Miura, 1986; Miura & Hess, 1983; Schubert, 1984). They may even actively discourage girls' intellectual achievement. In a study done by Aisenberg and Harrington (1988), one woman recalled her parents saying, "Don't be too big for your britches. Just because you get all A's, don't be a 'smarty-pants'" (p. 11). The statement is perhaps typical. Moreover, significant others show paltry expectations of females' computer competence. In a study designed to explore significant others' expectations of females' computer competence, 2,400 students and their teachers were asked to identify the competent programmers in a classroom. They chose only 45% of these as female. However, results from tests measuring programming competency, within the same group, revealed that females constituted 62.5% of the competent programmers (Mandinach & Linn, 1987).

Cognitive

Some researchers have tried to explain girls' minimal usage of the computer at this early age by attempting to link it to a deficiency in required computing skills.[3] The NAEP Report for 1977-78 and a more recent California Assessment Program Report (Fetler, 1985), indicated that boys in the 6th grade possessed higher computing ability levels than did the girls. Nevertheless, these ability levels were shown to be directly related to previous experience and boys were found to be more experienced with computers than girls (Carpenter, Coburn, Kepner, Lindquist & Reys, 1981; Fetler, 1985). However, studies done in Oregon, New Jersey, California, and Wisconsin found that girls and boys with similar programming experiences also had similar computing abilities (Fetler, 1985; Dalbey & Linn, 1986; Linn, 1985a; Linn & Dalbey, 1985; Lockheed, 1985b; Sanders, 1984). Moreover, Webb (1985) examined 11 to 14 year-olds who were experiencing parallel programming activities and discovered that the only difference between girls and boys was girls' significantly higher nonverbal reasoning abilities.

The literature focusing on the differences between girls' and boys' computing abilities at the elementary and middle school levels presents mixed and inconsistent results. However, it shows, rather consistently, that computing ability and experience go hand in hand. When girls had as much prior experience with computers as boys they were as computer competent as boys.

Psychological

Attitudes towards computers are determined in the California Assessment Program by asking students to respond to statements, such as the following: Computers treat everyone as a number; the more computers are used the less privacy there is; a knowledge of computers will help one to get a better job; to work with a computer a person must be a mathematician. Sixth graders' responses to these and other questions clearly indicated that both girls and boys had positive attitudes towards computers (Fetler, 1985). These findings have been replicated in other studies (Gardner, McEwen & Curry, 1986; Mandinach & Fisher, 1985).

Despite this, when other researchers (Chen, 1986; Eastman & Krendl, 1987; Gardner et al., 1986) asked girls and boys to describe how they felt about their computer-related abilities, girls, though significantly less than boys, reported that computer activities were more appropriate for male students and that girls were less computer competent than boys. Girls' feelings of computer incompetence persisted even when they had high levels of computer-related achievement (Breakwell & Fife-Schaw, 1987; Linn, 1985b, 1985c; Mandinach & Corno, 1985; Miura, 1986; Wilder, Mackie, & Cooper, 1985).

Miura (1986) found that girls' feelings of competence increased as they became more experienced with the computer. Miura followed for a three-year period, from grade six through eight, a group of students who were involved in computing activities. She discovered that female students reported increasing levels of confidence in their computing abilities. However, during this same period, girls' use of the computer decreased sharply. This was not true of male students.

Female High School Students' Experiences

Environmental

High school appears to accentuate the problems that female students encounter with computer science at elementary and middle school levels. National studies, as well as others done in California, Maryland, Michigan, and New York after 1981, reported that only 18% to 47% of the students enrolled in beginning programming courses were girls (Becker & Sterling, 1987; Kreinberg & Stage, 1983; Linn, 1985b; Lockheed, 1985a, 1985b; Miura & Hess, 1986). Intermediate programming courses were reported to have even fewer female students: less than 10% of the total enrollment (Hawkins, 1985; Linn, 1985b; Lockheed, 1985a, 1985b). In addition, only one-third of the test takers of the Advanced Placement Examinations in computer science in 1988 were women (National Science Foundation, 1990).

Moreover, most high school girls were reported not to have participated in extracurricular computer-related activities at school, such as computer clubs (Chen, 1986). In addition, the Educational Testing Service and others (Becker & Sterling, 1987; Lockheed & Frakt, 1984) reported that less than 8% of the female students voluntarily used the computers at school during free-time, as compared to more than 50% of the male students.

High school female students also were reported to be involved in fewer computer-related activities outside of the school environment. Miura and Hess (1983) examined surveys returned to them by 23 computer camps and reported that only one-quarter of the campers were girls. Moreover, they found that the proportion of female campers was inversely related to the cost of the camp--parents probably were less willing to finance their daughters' acquisition of computing skills.

Also, as was the case with their elementary and middle school counterparts, high school female students were reported significantly less likely to have access to a home computer than were male students (Chen, 1986; Fetler, 1985; Lockheed, 1985a, 1985b; Lockheed & Frakt, 1984; Wilder et al., 1985). Furthermore, girls who had access to a computer at home used it less frequently than did boys (Chen, 1985). In addition, girls played significantly fewer video games than boys (Becker & Sterling, 1987; Fetler, 1985; Kiesler et al., 1983, 1985; Lockheed & Frakt, 1984).

Research indicates that some of the reasons for the disparate usage of computers by female and male students have to do with the sex bias of the available educational software and video games. Most of these, as one can easily observe, reflect stereotypical male interests. They often require the employment of aggressive and competitive strategies to solve the usually violent problems or situations they depict (Fisher, 1984; Lepper, 1985; Miura & Hess, 1983). Studies (Becker & Sterling, 1987; Fisher, 1984; Gilligan 1982; Kiesler et al., 1983; Lockheed & Frakt, 1984; Miura & Hess, 1983; Sanders, 1984) have shown that girls did not respond positively to this software. They decidedly labeled it "masculine."

Moreover, high school students are bombarded with advertising that identifies computer science with men. Computer magazines and television advertising, geared to this audience, most often show boys handling the computers

(Hawkins, 1985; Lloyd & Newell, 1985; Miura & Hess, 1986). In a content analysis of three popular computer magazines, Ware and Stuck (1985) discovered that girls were shown in only 3.8% of the illustrations and always in the role of learners, while boys were portrayed more often and in a variety of roles: learners, game players, repair technicians, or buyers.

Research also indicates that this masculine image of computer science was enhanced if the primary computer-using teacher in the school was a man. A national survey, conducted in 1984, showed that the majority of these teachers in secondary schools were men and that this predominance increased in higher socioeconomic status schools and in schools where the principal was a man (Becker, 1985). Interestingly, and perhaps predictably, female students were much more likely to join a computer club in schools where women were the primary computer-using teachers (Becker, 1985).

Cognitive

Because the male presence is so predominant in computer science, researchers have tried to determine if female students innately are less able to study this science. Their studies have examined high school students' computing abilities, and, similar to the findings at the elementary and middle school levels, their results also are mixed.

Lockheed, Nielsen, and Stone (1983, 1985) reported that girls were just as able to learn programming as were boys. Their conclusions have been replicated by several other investigators (Anderson, Klassen, Krohn & Smith-Cunnien, 1983; Webb, 1985). On the other hand, the California Statewide Assessment of 1982-1983 found that male students had more programming knowledge and more computing experience at home and at school than did female students. However, this analysis did not take into account the relationship between experience and knowledge and, therefore, its findings are inconclusive (Fetler, 1985). In two other studies, Webb (1985) and Anderson (1987) compared the abilities of female and male students who possessed similar levels of experience. In their studies girls scored higher on problem analysis, algorithm application (Anderson, 1987), nonverbal reasoning abilities, design planning, and operational planning (Webb, 1985). Boys scored equivalently with girls on all other computing ability measures (Anderson, 1987; Webb, 1985). In light of the above, one might conclude that female students are not handicapped in learning computer science because of some innate deficiencies. Rather, female and male ability appear to be linked directly to the kind and quantity of computing experience the student has accumulated.

Psychological

The lack of female students' participation in high school programming classes, thought to be influenced by students' beliefs that computers are closely identified with males (Dearkin, 1984; Lockheed, 1985a, 1985b; Shore, 1985), may be compounded by girls' incorrect assumptions that a background in advanced mathematics and the hard sciences, physics and chemistry, is required for computer programming (Cole & Hannafin, 1983; Fennema, 1981; Hawkins, 1985; Miura, 1987) and by the stereotypic masculine image of mathematics and science (Ernest, 1976; Fennema & Sherman, 1977; Nash, 1975; Parsons, Adler, & Kaczala, 1982; Sherman, 1980c, 1982; Sherman & Fennema, 1977; Stein & Smithells, 1969; Vockell & Lobonc, 1981). Hawkins (1985) wrote:

> This treatment of computers as a topic subsumed under science/math/technology has serious educational consequences for girls. Because they are most often linked with an area that has long been dominated by males, computers typically enter the classroom with an aura of sex-related inequities that has an impact on both learners and teachers. (p. 167)

Numerous studies have examined whether or not high school students perceive mathematics and science as more appropriate for male students. Some of them (Ernest, 1976; Fennema & Sherman, 1976, 1977; Nash, 1975; Parsons et al., 1982; Sherman, 1980c; Stein & Smithells, 1969) have shown that a majority of students believe this to be true while others (Armstrong, 1981, 1985; Brush, 1980, 1985) reported that students generally maintain a more neutral position.

However, in all of the studies that I reviewed, boys, more than girls, were shown to believe that mathematics and science were more appropriate subjects for male students and that the latter were more capable students of these subjects than were female students (Armstrong, 1985; Brush, 1980, 1985; Chipman & Wilson, 1985; Ernest, 1976; Fennema, 1977; Fennema & Sherman, 1977; Levin & Fowler, 1984; Nash, 1975; Parsons et al., 1982; Sherman, 1980, 1982; Sherman & Fennema, 1977; Vockell & Lobonc, 1981; Wilder et al., 1985). Whether or not this belief influences female student enrollment and achievement in high school mathematics and science courses is debatable. Chipman and Wilson (1985) concluded their comprehensive review of the literature on this subject with the following comment: "The stereotyping of mathematics as a male domain does not seem to show much promise as a variable predictive of either enrollment decisions or achievement" (p. 304). However, when a female student enrolls in an area of study predominantly composed of male students, who believe strongly that they are more capable and that the subject matter is more appropriate for them, one can easily surmise the negative impact this set of circumstances may have on her.

Computer science appears to have an even stronger masculine valence than either mathematics or science. Wilder et al. (1985) found that most students from kindergarten through 12th grade believed that computer activities were more appropriate for boys than girls. Nevertheless, in agreement with the studies done in mathematics and science, female students in this study, maintained this belief less strongly than their male counterparts at all levels. Although many girls believed that computer-related activities were appropriate for them, they appeared to lack confidence in their ability to successfully participate in these endeavors (Chen, 1986; Gardner et al., 1986). This has been called the "We can but I can't" attitude (Chen, 1986, p. 274) and probably results in the avoidance of participation by many capable girls.

Albert (1987) showed that confidence in one's computer-related abilities and interest in computers were linked to perceived parental encouragement. Unfortunately, girls received less encouragement than boys from their parents (Hess & Miura, 1985; Miura & Hess, 1983, 1984; Schubert, 1984) and from their friends (Chen, 1986) to study computer science.

Girls, more often than boys, expressed a lack of confidence in their computing abilities (Albert, 1987). This held even when investigators controlled for experience and achievement (Chen, 1985; Cole & Hannafin, 1983; Wilder et al., 1985). Concomitantly, Albert (1987), using the Bem Sex-Role Inventory, found that a masculine or androgynous gender role identity was positively associated with computer confidence.

Computer anxiety--"the mixture of fear, apprehension, and hope that people feel when planning to interact or when actually interacting with a computer" (Rohner & Simonson, 1981, p. 551)--also has been suggested as a contributing factor in girls' lack of confidence and participation in the study of computer science. Several writers have hypothesized that, given the legacy of stereotypic sex roles, girls may be more vulnerable to these feelings of computer anxiety than boys (Martin, 1990; Shore, 1985; Simons, 1985; Winkle & Mathews, 1982; Martin, 1990). In a study of first-time computer users done by Williams, Coulombe, and Lievrouw (1983), computer anxiety perhaps was present. In their study, comparing girls and boys with similar levels of experience, girls, from kindergarten through high school, felt "slightly less at ease" than boys when using computers for the first time.

Although girls may experience computer anxiety more often than boys, many researchers have found that both high school girls and boys have positive attitudes towards computers (Albert, 1987; Chen, 1986; Durndell, MacLeod, & Siann, 1987; Wilder et al., 1985); however, girls seemed less positive than boys (Chen, 1986; Lockheed & Frakt, 1984; Wilder et al., 1985). The present researcher questions the validity of the statements used to determine attitudes toward computers. For example, "computers complicate and slow down business operations," "computers treat people as numbers," are samples of statements used to measure attitudes toward computers (Fetler, 1985). They appear more appropriate to measure one's perception of reality than one's attitude toward computers.

When high school boys and girls had similar levels of prior experience with computers, they were found to have similar attitudes towards the machines (Bell, 1980; Lockheed, 1985b). Despite this, beginning with grade 6 and thereafter, female students were shown to have declining interests in computers and to make significantly fewer plans to be involved in the study of computer science than boys (Breakwell & Fife-Schaw, 1987; Chen, 1986; Gordon, 1983; Miura, 1986; Targ, 1984; Wilder et al., 1985). Consequently, only 2% of the women entering college in 1988 chose to study computer science, a decrease from the 9% who had chosen it in 1983 (National Science Foundation, 1990). The 2% figure applies to all public and private higher education institutions; for public universities, the figure is 1% (Higher Education Research Institute, 1988). In other words, a mere 1% or 2% of the incoming undergraduate female students selected computer scientist as their probable career occupation. In this same year, incoming undergraduate male students made this choice 2 1/2 times more often.

Factors Influencing Success and/or Continuance in Undergraduate Computer Science

Several studies (Breakwell & Fife-Schaw, 1987; Casserly & Rock, 1985; Chipman & Wilson, 1985; Daly, Bell, & Korinek, 1987; Deboer, 1984, 1986, 1987; Durndell et al., 1987; Ethington & Wolfle, 1988; Greenfield, Holloway, & Remus, 1982; Jagacinski, 1987; Meece et al., 1982; Trigg & Perlman, 1976; Vetter, 1981; Ware & Lee, 1988) have examined the factors involved when a female student chooses to major in a field predominantly composed of men. Although fascinating, they are not included in this review because they touch my present concern only marginally. The present study focuses, not on the choice process and its contributing factors, but on the experiences female undergraduates encountered after they have decided to become involved in the study of computer science. It is directed toward the 1% or 2% of the women who chose to study computer science upon entering college.

I have included in this section the studies that have examined initial encounters with the educational environment of computer science and the computer culture, as well as those that have explored women's beliefs and feelings about the computer. In addition, I also have included works that have attempted to identify success predictors in required courses and continuance in a computer science major. Most of these studies did not distinguish between females' and males' experiences. The few that did are clearly noted, and the differences they found are inserted directly in the appropriate context.

Environmental

Significant Others' Encouragement

Female undergraduate students who made non-traditional career choices, which required more extensive computer work, reported receiving less support in planning these careers than did their female counterparts who chose traditional careers (Boulle-Lauria, Sedlacek, & Waldo, 1985).

Participation in and Availability of Experiences Using the Computer

Kay, Lublin, Poiner, and Prosser (1989) reported that undergraduate women experienced difficulty in beginning courses if they had not had prior experience with computers. Women, they stated, believed that teachers expected them to have experience, even though they had none and it was not required (Campbell, 1984). Research (Campbell, 1984; Franklin, 1987; Greer, 1986; Nowaczyk, Connor, Stevenson, & Hare, 1986; Ramberg, 1986) has shown that students who had computing experience prior to entering the undergraduate study of computer science withdrew significantly less often. In studies done in the United States (Campbell, 1984; Durndell et al., 1987; Evans & Simkin, 1989; Howerton, 1988;

Konvalina, Wileman, & Stephens, 1983; Martin, 1984; Nowaczyk, 1984; Oman, 1986; Taylor & Mounfield, 1989), prior experience was shown to be the most consistent predictor of both continuance and successful achievement in this area of study. Female undergraduates consistently were reported to have had substantially fewer prior contacts with computers than male students (Durndell et al., 1987; Kersteen, Linn, Clancy, & Hardyck, 1988; Miura, 1987). These conditions help one understand why the majority of female students withdrew during their initial study of undergraduate computer science (Campbell, 1984; Campbell & McCabe, 1984).

High School Mathematics and Science Courses

The number of semesters of mathematics taken in high school also has been demonstrated to be an important predictor of success in the beginning college computer science courses (Alspaugh, 1972; Butcher & Muth, 1985; Dey & Mand, 1986; Konvalina et al., 1983; Oman, 1986; Werth, 1986) and of continuance in the program (Campbell, 1984; Campbell & McCabe, 1984). College-bound female students in 1988 reported having an average of 3.6 years of high school mathematics, while male students reported having 3.8 years (National Science Foundation, 1990). This mathematical disadvantage appears to be a factor in women's early dropout (noncontinuance) from computer science (Kay et al., 1989).

Computer Culture

The available evidence indicated that the initial encounters with the study of computer science proved fatal to most of the women choosing to major in this field. Campbell (1984) found in two separate studies that only 31% and 39%, respectively, of the women choosing a computer science major remained after the first year of required courses. This is shocking in light of the formidable barriers over which these women had already hurdled in order to enter the undergraduate study of this science. Incidentally, these same studies showed that 55% and 61% of the males retained their majors after the same year of study.

Other investigators (Dubrovsky et al., 1986) have identified some of the reasons for this debacle. They found that the computer environment "is not just something new, but something alien" (p. 316) to both female and male novice undergraduate students. They uncovered major differences between computer and traditional coursework. Computer science courses required that students do their homework in computer laboratories on terminals and/or computers. For beginning computer users, these machines often were temperamental and seldom cooperative. Students reported that the screen would go blank arbitrarily, or the machine would "crash" and their work, completed to that point, would be "lost." Moreover, syntactic perfection was required or the machine would "refuse" to execute the student's program. Sometimes, even when all had been done properly, the computer's response could be very slow. In a word, many aspects of the computing environment appeared outside the student's control and thus were baffling to the inexperienced student.

Dubrovsky et al. (1986) also pointed out that students learning computer science must

> make their way through a host of arbitrary conventions that are totally unrelated to the science or theory of computing. A new student is thrown into a sea of syntax, I/O devices, priority classes, programs, and system quirks with no conceptual life vest to keep him [sic] afloat. (p. 316)

They compared the experience to playing a game without knowing the rules and added that students often had to wait in long lines to gain access to a machine. Frequently, new students had to compete for access against experienced users who appeared to be totally at ease with the computer and computing resources.

These researchers further described students' initial encounter with the educational computing environment as a rendezvous with an alien culture. Other investigators showed that this culture was particularly alien to women (Kiesler et al., 1983, 1985; Sproull et al., 1984; Turkle, 1988). A study done at Carnegie-Mellon determined that female students were more likely to encounter negative experiences during their initial encounters with computers than were male students (Kiesler et al., 1985). New students experienced reality shock when entering this new culture and their socialization occurred "under conditions of strangeness." Dubrovsky and colleagues (1986) stated:

> Novices must learn how to learn as well as what to learn. They must develop new ways of assimilating information and a new framework for it. They must learn how to recognize and interpret cues, and whom to rely on as informants. They must learn how to organize new bits and pieces of knowledge into coherent theories of behavior. (p. 317)

They added, "Our findings suggest the fallacy of thinking about the introduction of computing as simply imparting technical skills. Cultural experiences and socialization processes are also important" (p. 337).

In this same study, Dubrovsky et al. (1986) compared a public research-based and a private teaching-based university and found that students in the research-based institution were more likely to experience reality shock and confusion when encountering the computing culture than their peers. Further, the students at the research-based institution were more likely than their counterparts to undergo anger and withdrawal in response to their encounters with this culture.

The masculine image of the computer culture is further evidenced by the advertisements appearing in the leading computing magazines. Recent studies (Marshall & Bannon, 1988; Ware & Stuck, 1985) of major computing journals reported that men were shown in 90% of the illustrations using humans. Women were shown alone in less than 10% of the illustrations represented in three major magazines that were analyzed over a five year period (Marshall & Bannon, 1988). In 38% of the advertisements, they appeared with men. Most of these reflected sex-stereotypes and 17.2% of them contained sex-biased language.

The male image of the computer culture also is bolstered by software, the product of computer scientists's work. Miura and Hess (1986) asked women enrolled in undergraduate computer science courses to specify whether or not the software packages used in the courses appealed to them. They found that only 15% of the software appealed to the women. (Forty-five percent of the software was rated equally by both men and women.)

Cognitive

High School and College Achievement

Students' continuance in computer science appeared to be related to high school rank (Campbell & McCabe, 1984), high school grade point average (Evans & Simkin, 1989; Konvalina et al., 1983), and high school mathematics and science grade point average (Dey & Mand, 1986; Nowaczyk, 1984) for students enrolled in beginning college computer science courses. However, when Campbell (1984) attempted to identify continuance predictors for female students, she discovered that females' high school rank was negatively correlated to their continuance in the program. Campbell

(1984) suggested that perhaps female students withdrew when their grades did not meet their expectations.

The results of studies attempting to relate several different variables with success in beginning college computer science courses are mixed. One study (Wileman, Konvalina, & Stephens, 1981) found no relationship between high school mathematics and science grade point average and success in beginning undergraduate computer science courses; another study (Nowaczyk, 1984) found a positive correlation with English grade point average and success in these courses; and still another (Sauter, 1986) reported that foreign language skills contributed more significantly to success in them than mathematical skills. Several researchers (Fowler & Glorfeld, 1981; Petersen & Howe, 1979; Werth, 1986; Whipkey and Stephens, 1984) found college grade point average to be predictive of success in beginning computer science courses for majors.

Aptitude Tests

IBM's "Programmers Aptitude Test" (Mazlack, 1980) and Konvalina et al.'s "Computer Science Placement Exam" (1983), used to determine a person's aptitude for programming, showed almost no correlation between this aptitude and a student's success in beginning undergraduate computer science courses (Alspaugh, 1972; Butcher & Muth, 1985; Greer, 1986). In fact, the attempts made to identify predictors of success and continuance in undergraduate computer science have produced inconclusive results. Wileman and colleagues (1981) found no single measure that could be used to predict success and continuance reliably. Moreover, Butcher and Muth (1985) and Whipkey and Stevens (1984), using combinations of possible predictors (high school GPA, SAT scores, college GPA, number of high school mathematics and science courses, high school mathematics and science GPA) failed to predict more than 36.6% and 57% respectively of the successful students.

Psychological

Computer Anxiety

The shock and confusion experienced during initial encounters with computers may be aggravated by computer anxiety. Some studies have explored the effects of computer anxiety upon undergraduate students. They have demonstrated that it adversely affected computer achievement (Loyd & Gressard, 1984; Totoro, 1989), even more than prior computing experience (Marcoulides, 1988). Leamon (1987), Totoro (1989), and Pedersen (1989) have shown that a significant relationship existed between the level of computer anxiety and prior computing experience. Marcoulides (1988), on the other hand, found that students experienced computer anxiety despite prior experience and, though it decreased as they acquired more experience, the relationship between the two parameters was weaker than he had expected. Several researchers found that women and men felt the same level of computer anxiety (Leamon, 1987; Loyd & Gressard, 1984; Marcoulides, 1988) while others, perhaps because they did not account for prior experience, noted significant differences between the two sexes (Abler & Sedlacek, 1986).

Personality Traits

The conclusions from studies that explored personality traits and their relationship to success in beginning undergraduate computer science courses, also are mixed. For example, some researchers found that students were more likely to succeed if they were introverted (Werth, 1986), perfectionist, and detail-oriented (Kagan & Pietron, 1986), while others failed to find any correlation between personality traits and success in these beginning courses (Petersen & Howe, 1979; Whipkey & Stephens, 1984).

Computer Self-Efficacy and Self-Ratings of Computer Competence

Miura (1987) showed that self-efficacy, a belief that one can successfully complete a certain course of behavior (Bandura, 1977), influenced acquisition of computing experience. The same researcher found that: (a) Female students had significantly lower levels of perceived computer self-efficacy than their male counterparts; (b) computer self-efficacy expectations were positively related to plans to take, and enrollment in, a computer science class in college; and (c) the completion of a programming course in high school and/or college was the most important predictor of computer self-efficacy.

Students enrolled in computer science courses were reported to attribute success to external factors and failure to internal factors (Sproull, et al., 1984). In other words, undergraduate women and men did not ascribe their success in these classes to their abilities.

In addition, other researchers reported that women believed that other women as well as men (Jackson & Yamanaka, 1985), knew more than they did about computers.

Beliefs in Usefulness of Computer

Some researchers (Pullman & Parsegian, 1987) reported that women believed more strongly than men that a working knowledge of computers is as fundamental as the knowledge of reading and writing. Other researchers (Breakwell & Fife-Schaw, 1987) showed that men believed more strongly in its usefulness.

The results of the research focusing on undergraduates' feelings towards computers are conflicting. On the one hand, Pullman and Parsegian (1987) found that women felt more positively toward the computer than men: Women were reported to find them more pleasurable, humorous, sensitive, spacious and public. On the other hand, Abler and Sedlacek (1986) and Dambrot (1985) found exactly the opposite: Men were more positive toward the computer than women.

In summary, the picture of female undergraduate computer science students that emerges from the studies reviewed in this section is incomplete, mixed, and often conflicting. Some of the studies did not attempt to show a relationship between a particular characteristic and its effect on the success and/or continuance in computer science. Others did not examine separately female and male students. However, those that did examine female students' involvement in undergraduate computer science consistently found that: (a) women felt the computer culture to be especially alien (Kiesler et al., 1983, 1985; Sproull et al., 1984; Turkle, 1988); (b) more often than not, they experienced negative initial encounters with the computer and its culture (Kiesler et al., 1985); (c) only about one-third of the women continued after the first year of required courses (Campbell, 1984; Campbell & McCabe, 1984); (d) women with no prior computing experience were much more likely to withdraw from beginning courses (Campbell, 1984; Campbell & McCabe, 1984; Ramberg, 1986); (e) they were more successful than (Evans & Simkin, 1989), or as successful as (Whipkey & Stephens, 1984), their male classmates; (f) most often, they experienced as much computer anxiety as their male counterparts (Leamon, 1987; Loyd & Gressard, 1984;

Marcoulides, 1988); (g) they did not believe in their own abilities (Jackson & Yamanaka, 1985; Miura, 1987; Sproull, et al., 1984); and (h) women usually did not feel negative toward the computer itself (Abler & Sedlacek, 1986; Breakwell & Fife-Schaw, 1987; Pullman & Parsegian, 1987).

Women's Recollections of the Undergraduate Experience

In this section of the review of the literature, I report on women's recollections of their experiences while studying undergraduate computer science. The material is sketchy and quite limited. However, the few tidbits of testimony that I have gathered, provide clarifying insights into these women's experiences.

For example, women reported that they were considered "deviant" by significant others when they chose a computer science career (Kurland & Cahir, 1984). Because they are different from most of the students in computer science they might, as one woman described, have "trouble establishing working partnerships with other students" (Kersteen et al., 1988, p. 328). She did. She believed that because of this she was "at a serious disadvantage" and accordingly received an unsatisfactory grade in the course (Kersteen et al., 1988, p. 330). Another woman, who received an A in this same class, credited the formation of "a very solid lab partnership early in the semester," with an experienced student, as a major factor in her success (Kersteen et al.,

p. 328).

Women identified language as another source of difficulty for them. One woman commented, "The use of jargon, especially in the first year, was confusing" (Kay et al., 1989, p. 518).

Female computer science students interviewed by Kay et al. (1989) invariably talked about the amount of time they were required to invest in order to succeed in computer science courses. They also discussed the accompanying stress. The weekly time commitment for the beginning course was estimated at 32.93 hours, on average (Martin, 1984). This led them to work in computer laboratories late at night, a circumstance that confronted them with particular problems (Sproull et al., 1984).

Female undergraduates also believed that the operating systems[4] in which they were required to work were "a major stumbling block in the road to learning how to program" (Kersteen et al., 1988, p. 329). The reasons for this belief were not given.

The analysis of interviews of 25 Harvard and M.I.T. undergraduate women conducted by Turkle (1988), who also has studied the computer culture for several years, revealed illuminating facets of women's interaction with members of this culture. Women who watched these persons--men obsessed with computers who "put things rather than people at the center of their lives," "count themselves out" (p. 46).

One woman said, "These guys are incredibly drained. You can't talk to them. I don't want to be part of their world" (p. 47).

Risk taking is a central mode of operation for members of the computing culture. According to Turkle (1988), it "has a gender valence"--boys learn as children to take risks while girls more often are "directed away from situations that might cause trouble" (p. 48). To use this type of learning strategy requires one not to take failure "personally." The women interviewed found this strategy difficult to implement. Turkle (1988) stated:

> When women look at the programming virtuosos around them, they, unlike men, see themselves as cut off from a valued learning style. Male risk taking is equated with computational "intuition." In educational and professional environments where hackers present an image of "the best," women often see themselves as lesser. They see themselves as "just users," as competent but not really creative. (p. 49)

These women also indicated that they fought against the computer's holding power. They believed that this power was commonly experienced by those working with computers and asserted that it was "seductive and dangerous." Therefore, to defend themselves against identifying with the machine they insisted that the computer was "just a tool." Turkle (1988) wrote:

> The more they anthropomorphize the machine, the more they express anxiety about its dangers . . . The more they experience the subjective computer, the more they insist that it doesn't exist and that there is only the instrumental machine. (p. 55)

The female undergraduates in Turkle's (1988) investigation objected to being taught to employ "structured programming" when creating an automated problem solution--a computer program. This methodology emphasized "top-down" control and hierarchical organization. One of the women summed this in a word: "regimentation" (p. 59).

Turkle (1988) concluded her study with the observation that to be a woman is to be "opposed to a compelling relationship with a thing that shuts people out." For a woman, a technology that was demanded separation was "alien and dangerous" (pp. 50, 51).

Jagacinski, LeBold, and Salvendy (1988) concurred with Turkle's conclusions. In their research they found that women who withdrew from the study of computer science, desired more strongly to work with people and to make a contribution to society than those who persisted in computer science (p. 198).

In summary, female undergraduate computer science students generally view the computing culture as confusing, strange, regimented, dangerous, machine-centered, demanding, isolating, seductive, time-consuming, and male. In a word, alien.

Graduate Women's Experiences

Female graduate students and research staff at M.I.T. in 1983, while participating in the study or practice of computer science, wrote a report, Barriers to Equality in

Academia: Women in Computer Science at M.I.T (1983), in which they described their experiences. Although, this record directly did not address undergraduate education, it reflected so many of the experiences that I and the women I interviewed encountered as undergraduate computer science majors that I deemed it worthy of inclusion in this review.

The report examined two areas of these women's experience: professional and social. The women felt that both of these areas had a direct bearing on their ability to function as computer scientists. Their relationship with men in these two areas illuminated how men viewed female computer scientists.

In the professional area the women felt that their colleagues doubted their seriousness--they were surmised to be searching for a husband, rather than pursuing intellectual interests. Also, they were judged to be less qualified than men simply because they were women.

The male members of the computer science community saw these women first as women and then as professionals. As a consequence, the women experienced professional invisibility--their questions, comments and opinions were ignored and they were interrupted and talked over in group settings. One female student said, "I know men who ignore my questions about their work, but respond to a man who asks the same questions" (p. 8). Another stated:

> I was the only woman in a group working on a machine. Only one person could use the machine at a time.

> Often, while I was working on a task, a male graduate student would physically push me away from the machine and interrupt my work so that he could get at the machine. This didn't happen to the men in the group. (p. 8)

When the women asked men for help, often they encountered patronizing condescension. Not uncommonly, men would say, "We'll see how we can fix things for you so they're better" (p. 9). Typically, men would "do it for me rather than explain to me how I can do it for myself" (p. 9). Or they would explain the question as to a beginner. One woman said, "I got an answer that seemed to be aimed at someone with little or no knowledge of computer science, as if it were being explained to a high school student rather than a colleague" (p. 9).

Female students who visited professors in their offices to ask questions about a course, assignment, or research project often were misinterpreted. For example, one woman reported, "The following gestures made by me were interpreted as 'come-ons': (a) looking him directly in the eyes, (b) smiling while talking to him, and (c) leaning back in my chair" (p. 14).

In the social area, these women found themselves more or less excluded from interactions that were vital to professional success. They felt inhibited from developing friendships because they ran the risk of attracting the wrong kind of attention. Their frustration was aggravated by their male colleagues' usual assumption that if they were not in a permanent relationship with someone they were "available and looking for a romantic relationship" (p. 4). In addition, since they were a small minority, persons with whom they worked treated them differentially and this made it even more difficult for them to interact socially. Furthermore, the "locker room atmosphere," that included posters, pictures, sexist jokes, and inappropriate attention to them, accentuated their feelings of social ostracism.

Isolation and stress were end products of these women's academic and social experience. In time, they had quit talking to male faculty and students because their attempts to discuss academic work were misinterpreted. Though they were "comfortable talking to female students," there was an overwhelming male presence in their environment that caused them to feel separate and isolated (p. 15). Their feelings of isolation were heightened when obscene mail was "sent over the computer system from male students" (p. 17). One woman concluded, "I feel like I can never have any friends here, like I can never fit in. I've never felt so isolated in my life" (p. 18).

Computer Science Teachers

The problems for women who are involved with computer science, witnessed all along these pages, do not appear to have ready solutions. If, as I believe, the access of female students to undergraduate computer science depends, to a great extent, on an abundant presence of female faculty, the solution perhaps is years away. A recent report from the National Science Foundation (1990), entitled Women and Minorities in Science and Engineering, stated that female computer science graduate students received 29.9% of the masters degrees awarded in 1986 and a mere 10.9% of the doctorates awarded in 1988. This small representation of degrees has not changed substantially for over a decade (1978-1988). Although, an even more recent report, the 1988-89 Taulbee Survey Report indicated that women received 13.9% of the computer science doctoral degrees awarded in 1989, they still constitute a mere 7% of all computer science teachers in doctorate-granting institutions (Gries & Marsh, 1990).

As previously stated, the number of women decreases as one moves from high school to graduate school. At the teaching level, very few of them remain. And their numbers continue to decrease as one ascends the rungs of professorship. Based on reports from 158 doctorate-granting universities in the United States, Gries and Marsh (1990) gave the following account: (a) One-third of the computer science departments in these universities have no female faculty members; (b) of the 2,550 computer science teachers in these universities, women constituted 10% of the assistant, 9% of the associate, and only 3% of the full professors.

The literature does not indicate that there is a great deal of encouragement for women who work as faculty persons in a college or university computer science department. Even though no one has yet studied this small group of individuals, a recent study done in Australia by Kay et al. (1989) shed some light on faculty women's plight. These researchers interviewed 19 computer science faculty who were charged with teaching beginning computer science courses. They reported on the views of a few male faculty members. One faculty member said, "I'm sure that if we had more women they would tend to feel less threatened through greater mutual support. The male technocratic ethos is appallingly powerful" (p. 524). Another remarked, "The only bias in this department is the total absence of female academic staff" (p. 524). Although the above information is scanty one can assume that women probably would encounter at this level some of the same isolating, frustrating, and alienating conditions they had faced all through their years of schooling.

These professors held several stereotypic beliefs about women that were potentially damaging to female students' achievement: (a) Women are the "pedestrian workers, rather than the high flyers" (p. 523); (b) they are "timid, less confident, less experimental or adventurous" (p. 523); and (c) they do not work independently, are not self-reliant, and often ask for help.

How widespread are such views among computer science faculty members? Is there a correlation between the views held by faculty teaching the beginning undergraduate computer science courses and female students' withdrawal rates? One only can surmise the answer to these questions. However, I believe, the presence of more female faculty members would begin to ease female teachers' feelings of isolation, provide more role models and mentors for incoming female students, and facilitate the latter's continuance in computer science.

Female Professionals

To round off the many ramifications of women's involvement with computer science, I next briefly explore the experiences of women employed as computer professionals. My chief source of information in this area was Lloyd and Newell's Women and Computers, published in London in 1985. The experiences they related, their own and those of other women in computing, again portrayed an environment inimical to women. They wrote:

> There is an increasingly strict hierarchy among computing jobs. At the bottom are the people--almost invariably women--who perform keyboard operations in the process of preparing data for computer input. (p. 240)

Strober and Arnold (1987) concurred with this and added, "Among four computer-related occupations found in all industries--computer scientists/systems analysts, computer programmers, computer operators, and data-entry operators--the higher the status and pay of the occupation, the more white men were overrepresented" (p. 171).

It was at these higher levels of employment that women again found the familiar alienation and frustration born of underrepresentation. As was the case in academia, women in the higher echelons of the computing professions, were not treated professionally. Lloyd and Newell reported often being greeted with surprise, dismay, or incomprehension by male colleagues. "You don't look like a computer person." "Isn't it a rather odd thing for you to do?" "Heavens, you must be brainy" (p. 246).

Moreover, the working environment was made more strange for women by "the pervasive air of male camaraderie which, by definition, excludes them and often serves to keep women under control" (p. 246). Many informal meetings were held in a "very gender-specific, masculine place--the pub," which made the entrance of women into the "charmed circle of camaraderie among co-workers" extremely difficult (p. 247).

In addition, Lloyd and Newell stated, "Women who work in computing do so on terms which have been laid down by men" (p. 247). The personal qualities needed to succeed are "those usually associated with men--hard-headedness, single-mindedness, ambition, toughness" (p. 247). Besides, "working late at the office was a prerequisite for promotion" (p. 247).

Women in the computing professions are not only underrepresented. They also are underpaid. The National Science Foundation (1990) reports that 30.9% of the employed computer specialists in 1988 were women. These women's salaries, during the same period, averaged about 86% of those of men. Women experience difficulty working under these conditions.

Summary

Everywhere, from elementary to graduate school and to teaching, women find involvement with computer science difficult and alienating. Despite their initial interest and demonstrable ability in computers, their numbers gradually decline. Thus, female representation in computer science decreases from 50% in middle and high school required courses to 30% in college and continues to decrease throughout graduate school until women are only 7% of the computer science teachers at doctorate-granting institutions.

In the computing industry, women do not fare better. Generally, when new and more highly paid jobs are created, these are filled by men. Women tend to staff the openings at the bottom.

In 1989, the National Science Foundation created an advisory committee, chaired by Leveson, to study reasons why this abysmal picture of women's involvement with computer science exists and to offer suggestions for increasing the number of women in this science, especially in research. The conclusion of this report, "Women in Computer Science," released in December, 1989, was: "There is a problem--women are dropping out in the pipeline at a much higher rate than men--and something must be done about it" (Leveson, 1989, pp. 6,9).

Although the above described scenes are sketchy, they are comprehensive enough to elicit a dismal and alarming picture. They also authenticate my own experience and that of the other women who participated in this study. In addition, they continue to fuel my desire to radically alter the existing undergraduate computer science program and to create a learning environment that is equitable and facilitatory for all students.

Notes

[1]The study of computer science revolves around structural and procedural tools needed to analyze, design, implement, validate, and maintain automated simulations of real-life systems.

[2]Most studies addressing sex differences generally show large intra-sex differences but negligible inter-sex variance. The latter studies usually are published, seldom the former.

[3]For a list of these computing abilities see (b), p. 18.

[4]The software that one is required to use in order to operate a computer. The operating system allocates the resources of the computer.

CHAPTER III

METHODOLOGY

Introduction

This research endeavor was guided by two theoretical fields of thought, feminist methodology and grounded theory, which, although distinct from each other, share many common themes. I have amalgamated these two methodologies, integrated their basic principles, and applied them to the current research endeavor. This chapter includes accounts of feminist methodology and grounded theory, as well as a synopsis of the history of their development. A description of the amalgamation of these two theoretical constructs as it is used in the present research effort completes this discussion.

Philosophical Basis

Feminist Methodology and Scholarship

Virginia Woolf (1938) contributed to the discourse leading to the construction of feminist methodology and scholarship when she stated in Three Guineas that "science it would seem is not sexless; she is a man, a father and infected too" (p. 139). Formalized feminist methodology, however, grew out of a social movement or consciousness in the 1960s. Women began to claim equality. Many in higher education joined in this demand and presented substantial evidence for our claim. We[1] conducted "meticulous studies, analyzing and pinpointing differential treatment or even differential effects of similar treatment" (Meyer, 1988, p. 106). During this process we became aware of the inadequacy of the currently accepted scientific methodologies, the "scientific method", to produce new information that could illumine tacit assumptions and conventional beliefs. We needed to unearth these underlying assumptions so that we could begin to understand the oppression of women and others in our society. We also needed to develop new postulates wherein control and power could be seen as central constructs in maintaining the status quo (Wallston, 1985) rather than to utilize accepted theories in which reasons purported to be innate in women were used to justify the existing situation. Feminist methodology, a term used during the last two or three decades, refers to a manner in which women and men conduct research projects using this expanded base of assumptions and beliefs to examine oppressive situations and to propose alternatives to alleviate them. The resulting body of knowledge may be referred to as feminist scholarship.

The discussion of feminist methodology is divided into two sections. The first deals with feminists' illumination and criticism of traditionally accepted methodologies. Particular attention is paid to the tacit assumptions used by the "scientific method" and the effects of these assumptions on the research conducted and on its participants. The second is a description of feminist methodology as it is currently understood (Garry & Pearsall, 1989; Gergen, M., 1988; Gergen, K., 1988; Nielsen, 1990).

Illumination and Critique of The Traditional Approach

The formalization of this new theoretical base began with a deconstruction of the accepted hypotheses and methodologies. This required that critique assume a central role in feminist methodology (Christ, 1987; Dubois, Kelly, Kennedy, Korsmeyer, & Robinson, 1987; Haraway, 1987; Harding & O'Barr, 1987; Maher, 1985; Rose, 1986; Stanley & Wise, 1983). The critique has been focusing on all aspects of the research process. It has investigated why particular areas rather than others are chosen for study and the questions asked about those areas. It has analyzed the hypotheses generated and the assumptions inherent in them, as well as the methods used to explore the hypotheses. It has explored the possibility of generating objective or value-neutral knowledge about the topic under study. Further, it has probed into the principal investigator's effects on the entire process and the "facts" upon which the hypotheses were constructed. Finally, it has scrutinized the types of analyses employed to arrive at the conclusions and the uses and purposes for which the findings are used.

Challenging Tacit Assumptions

One of the primary tasks of feminist research has been to unearth and challenge the tacit assumptions that have guided traditional research efforts. This has involved questioning the fundamental, the unquestioned, and the unarticulated; speaking the unspoken; finding the unnoticed and hidden; naming the unnamed; challenging the most fundamental presuppositions and categories; analyzing gaps, missing information, irrationalities and blind spots; illumining the founding metaphors (Christ, 1987; Daly, 1973; Foss & Foss, 1983, in press; Pateman, 1986; Rosser, 1986; Schniedewind, 1983; Young-Eisendrath, 1988). In interrogating this forestructure of knowledge, we have been questioning not only the traditional use of the scientific method, but also the basic adequacy of the method itself (Gergen, M., 1988; Stanley & Wise, 1983), and even the very logic of empirical investigation as a whole (Unger, 1983).

Objectivity

Many feminist investigators have singled out the principle of objectivity as one of the most important unquestioned assumptions of traditional research (Bleier, 1984; Bordo, 1987; Christ, 1987; Fee, 1983; Harding, 1986, 1987; Hubbard, 1989; Keller, 1978, 1982, 1983a, 1983b, 1985; Keller & Grontkowski, 1983; MacKinnon, 1987; Sherif, 1987; Smith, 1987; Stenstad, 1989). Keller (1985) called it utopic at best and added that, though perhaps unconscious and unintended, the belief structures of researchers affect their findings--research cannot be produced in a vacuum. Freire (1985) enlarged on this when he wrote that, "Reality is never just simply the objective datum, the concrete fact, but is also people's perception of it" (p. 51).

Feminists believe, given women's status in society and the understanding that our previous experiences participate in current situations, there is no ungendered reality or ungendered perspective (Foss & Foss, in press). The principle of objectivity functions, in this context, as a denial "of the existence and potency of sex inequality that tacitly participates in constructing reality from the dominant point of view" (MacKinnon, 1987, p. 136). Moreover, "objectivity, as the epistemological stance of which objectification is the social process, creates the reality it apprehends by defining as knowledge the reality it creates through its way of apprehending it" (MacKinnon, 1987, p. 136). In other words, the roles one has been taught to play from childhood inform one's perception of reality thus negating the possibility of absolute objectivity.

Furthermore, the principle of objectivity denies that knowledge is relative and that epistemology is a function of our socioeconomic existence (Rawlins, 1984). In addition, it legitimizes itself by

> reflecting its view of existing society, a society it made and makes by so seeing it, and calling that view, and that relation, practical rationality. If rationality is measured by point-of-viewlessness, what counts as reason will be that which corresponds to the way things are, practical will mean that which can be done without changing anything. Objectivist epistemology is the law of law. It ensures that the law will most reinforce existing distributions of power when it most closely adheres to its own highest ideal of fairness. Like the science it emulates, this epistemological stance can not see the social specificity of reflection as Method or its choice to embrace that which it reflects. (MacKinnon, 1987, p. 141)

Hierarchical Ordering of Reality

Another tacit assumption inherent in conventional research methodologies is the hierarchical ordering of reality. Feminists believe that this is a "masculine" fallacy (Keller, 1982, 1985). Knowledge produced using this assumption has expressed situations under study as closed systems composed of binary opposites (Shotter & Logan, 1988). The resultant ordering has allocated a "proper place" to women that "happens to be" inferior to men (Irigaray, 1989; Stanley & Wise, 1983). Women are viewed in comparison to men, the standard. Women are given "less . . . than" attributions, for example, less intelligent, less objective, less competent, less aggressive, less mathematically able than their male counterparts (Young-Eisendrath, 1988).

Metaphors in scientific work reflect these androcentric assumptions (Beldecos et al., 1989). For example, hard science is said to be preferred to soft science, hard money to soft money, hard data to soft data (Bart, 1971). Feminists have suggested the use of "wet" science in preference to "dry" science as gynocentric metaphors (Hubbard, 1988).

Social Intervention

That the current practices of science do not have a bearing on the social structure is yet another assumption of the scientific method. Feminist critique has been particularly interested in illuminating this assumption inasmuch as it leads to maintaining and legitimating patriarchal domination--a self-serving structure of power and an androcentric ideology (Biklen & Shakeshaft, 1985; Christ, 1987; Gergen, K., 1988; Heide, 1985; Jacklin, 1987; Rose, 1983; Sayers, 1987; Stanley & Wise, 1983). That traditional science has intervened in social affairs is demonstrated by the mobilization of a reactionary ideological movement within this scientific community "to defend inequality, protect the status quo, and create barriers to change" in response to a movement for change in the social roles of women and men in the last thirty years

(Fee, 1986).

Social intervention by traditional scientists is further evidenced by repeated research efforts attempting to find sex differences in cognitive abilities (DuBois et al., 1987). These efforts generally have emphasized the findings of studies that report small inter-sex differences in cognitive abilities, while virtually ignoring the many studies wherein no differences or consistent large intra-sex or inter-cultural differences were found (Gould, 1987; Howe, 1983). Thus, conventional science, unable to cross the "threshold-of-convincibility" (Jacklin, 1987), has persisted in concentrating its attention in particular areas of research. This emphasis exposes the fallacy of social nonintervention and reveals the use of sociobiological theories as weapons of ideological warfare (Jacklin, 1987). Ironically, Kelly-Gadol (1987) noted, it was precisely during those periods of history celebrated for progressive change that women experienced further losses of status.

Value-Free Research

Traditional research also is purported and expected to be value-free, an assumption refuted by feminists (Gergen, K., 1988; Gergen, M., 1988). Longino (1989) believes that researchers must acknowledge their ability to affect the course of knowledge and to fashion or favor research programs that are consistent with the values and commitments they express in the rest of their lives. Thus, she added, "the idea of a value-free science is not just empty, but pernicious" (p. 54).

Values are exposed, for example, when describing the qualities of a scientist. "Masculine" characteristics are valued while "feminine" qualities are devalued and called unscientific (Namenwirth, 1986). The traditional methodologies have served to systematically exclude, whether intentionally or not, the possibility that women could be "knowers" or agents of knowledge. The voice of science, as conventionally defined, has been a masculine one. Women's research and scholarship have been trivialized, ignored, denigrated or appropriated without the credit which would have been given to men's work. "One of the notorious examples of this kind of sexist devaluation in the natural sciences is the treatment of Rosalind Franklin's work on DNA by her Nobel prizewinning colleagues" (Harding, 1987, p. 4).

Masculine methodologies, part of "a self-perpetuating and self-reinforcing system," have prevailed (Keller, 1983, p. 138). Male scientists have defined the acceptable rules according to their values. Studies have focused on areas of interest to men. The "truth," when it has been found, often has been exactly what researchers thought it might be right at the beginning (Stanley & Wise, 1983). This "truth" then has been used to suppress women from becoming involved in all aspects of research other than in supporting roles

(Namenwirth, 1986). In fact, in investigations into areas other than gender differences, women have continued to have minimal participation even as subjects. Often, if they have been included, they have been discarded from the data because they "confuse the results" (Meyer, 1988; Rich, 1979).

Claiming Creation of Knowledge Is Open to Anyone

Another assumption espoused by the traditional research community is that the creation of knowledge is open to anyone who is qualified. However, feminists have posited that sexism--institutionalized discrimination that renders women comparatively powerless--has continued to exist (Bernard, 1987). It can be seen in the conceptualization of problems, allocation of resources, operationalization of measures, nature of the control groups chosen, and sampling (Jacklin, 1987). In research about women and men, this bias often has been evidenced by an analysis that sees sex as genderless (Foss & Foss, in press) and by a view of differences between the sexes that is based upon "natural" variance. Conventional research has failed to realize that people have no intrinsic gender. We are not free to develop and define ourselves by our own choices and possess our "selves" as we possess other property. This erroneous view is a product of modern individualism, in which the individual is said to be free inasmuch as each person is the proprietor of one's person and capacities (Shotter & Logan, 1988).

Moreover, if a woman wanted to succeed in the traditionally sexist, discriminating scientific arena, she has experienced double-binds--"situations in which persons may incur some social penalty regardless of their behavior" (Unger, 1988, p. 132). For example, because the characteristics of a scientist exclusively are patterned on male models, in order to be a "real scientist" a woman must be unwomanly and to be a "real woman" she must be unscientific (Fee, 1986; Heilman & Saruwatari, 1979; Namenwirth, 1986; Wood & Conrad, 1983; Young-Eisendrath, 1988). Not only has a woman been viewed as out of place because of these criteria, but also because she is other than male. In fact, this out-of-place designation is marked linguistically when a woman is referred to as a woman scientist, or a woman doctor, physicist, geneticist, mathematician, engineer, software engineer, or a woman computer scientist. This type of differential marking does not occur when a woman is in "her place," as with occupations such as nurse and secretary where "woman" nurse or "woman" secretary would sound redundant.

Again, double-binds have occurred because behavioral options available to women are more apparent than real. This happens because so many contradictory stereotypes--"mother," "sex object," "pet," or "iron maiden," the four archetypal roles for women in Western society, according to some theorists, (Wood & Conrad, 1983)--appear to "fit" almost any behavior a woman opts for (Unger, 1988). These double-binds have arisen in changing segments of society, e.g., academia, more often than in traditional ones where more explicit behavioral constraints have operated to confine women's choices.

The most damaging aspect of double-binds is that they place responsibility for the resulting discomfort "upon the target individual who is defined as the 'intruder'--either by her mere presence or by her out-of-place behavior" (Unger, 1988, p. 135). For example, a physically attractive female manager represents a contradiction to traditional definitions of competence.

In brief, double-binds are subtle and destructive measures that operate to regulate participation in scientific inquiry in favor of male researchers.

Decontextualization of Phenomena

Moreover, feminist critique has acknowledged and rejected decontextualization of phenomena as practiced in traditional inquiry. Decontextualization occurs in at least two ways: (a) removal of the cultural and historical context through the use of a laboratory setting; and (b) removal of the life circumstances of the scientist from the study (Gergen, M., 1988). Often scientists have attributed to women, studied in isolation, qualities which they term "natural" or innate when these qualities are likely to be "acquired," stemming from women's social position as an oppressed group, or to result from the laboratory environment. In so doing, investigators have overlooked important social and cultural factors that influence and perhaps determine the so-called "natural" qualities of women (Bernard, 1973; Gergen, M., 1988). Thus, their conclusions often have supported androcentric biases (Marshall, 1986). M. Gergen (1988) has stated that to remove the scientist from the subject of study is limiting and androcentric. Chodorow (1978) espoused an identical view when she argued that men develop their personal identity by separating and differentiating themselves from their mothering agents. Perhaps what scientists consider as proper methodology for organizing reality is merely a by-product of male developmental history.

Feminists also have rejected the claim that facts are independent of the scientists who initiated them. The tacit assumption which underlies the belief in objective facts is that the world is as it is, independent of the observer, and, if all persons use proper scientific methods, they will arrive at the same conclusions regarding the same situations (Gergen, M., 1988). This position is arguably inexact. When one considers that facts are born of reasons and the latter are open to manipulation one can see how "facts" may be mere conjecture. Hubbard (1988) believes that making facts is a social enterprise controlled by a relatively small, homogeneous group of scholars and scientists. Feminist thinkers have been particularly critical of the ways in which these predominantly white, European, upper middle- and upper-class, university-educated men, accustomed to working in hierarchical institutions, regulate and control the access to the "creation" of facts. Largely, fact makers are "a self-perpetuating, self-reflexive group: by the chosen for the chosen . . . Public accountability is not built into the system" (Hubbard, 1988, p. 3).

The perpetuation of tacit assumptions inherent in traditional research is ongoing. It is potentially damaging because it may unwittingly reinforce falsehood, thus delaying the process of exploring and finding truth--a rather common occurrence in the history of science. This state of affairs need not, must not, continue. As other groups, other than the dominant one, are allowed to enter into the inquiry process, hidden assumptions will be exposed more readily. Each unspoken belief that is made explicit will assist in molding alternative methods. Hopefully, these methods will work to generate factual knowledge more akin to reality.

Construction of Feminist Methodological Theory

Solomon (1984) and Christ (1987) have pointed out that the major purpose for the construction of a new mode of inquiry is to spawn new and "impassioning" truth that will change the existing hierarchical social structure and transform the world we have inherited.

As previously stated, feminists have rejected the premise that scholarship is or can be objective and propose in its place that it be "intelligently subjective," that is, transcending the dichotomous categorizing of subjectivity and objectivity often used in traditional methodologies (Christ, 1987; Stanley & Wise, 1983). Christ (1987) has defined intelligent subjectivity as a

> process beginning in conscious awareness of one's own experience and standpoint, then passing over to the experience of another in order to understand the world from a different point of view, then returning to the now expanded standpoint of the self in an act of judgment that incorporates the insights learned from passing over into the standpoint of another into the standpoint of the self. (p. 59)

This approach to scientific inquiry also has been called "feminist objectivity," "positioned rationality," "situated knowledge" (Haraway, 1988; Keller, 1983; Longino, 1989), or "feminine intuition" and "objective empathy" (Young-Eisendrath, 1988). It is, in Freire's (1985) view "the indispensable unity of subjectivity and objectivity in the act of knowing" (p. 51). The feminist researcher does not aspire to being detached from and disinterested in one's topic of investigation, but rather uses involvement in it and passion for it as means to acquire insights unattainable from a purely objective perspective (Gross, 1986).

In addition to being a mode for understanding the participants in one's field of inquiry, intelligent subjectivity may serve as a checkpoint "against which existing theories and research are tried out" (Meyer, 1988, p. 120). For example, when trying to make unspoken assumptions explicit, one receives cues from "gut feelings," "intuitions," or "senses," sources of data that traditionally have been defined as subjective. These impressions, when shared and explored by the investigator and the participants, are useful in illuminating underlying tacit premises. Obviously, the "objective" premise cannot be challenged when using the premise of objectivity. One necessarily must expand the acceptable means available in order to examine more carefully these sanctioned postulates.

Rather than maintaining the "objective" distance required in traditional research, feminists propose to bring the scientist closer to the focal point of one's research effort (Jacklin, 1987). Some feminists have called this the "wet" approach to inquiry (Bart, 1971). The wet approach involves "naturalistic observation, sensitivity to intrinsic and qualitative patterning of phenomena studies, and greater personal participation of the investigator" (Carlson, 1972, p. 20). It includes a reconceptualization of nature and of participants as active, dynamic, and complex instead of passive, static, and simplistic. From this reconstructed view one may access discovery by cooperating with nature and participants instead of controlling and manipulating them (Fee, 1986). An example of a scientist successfully following this methodology is Barbara McClintock, a molecular geneticist (Gould, 1987), who believes in "letting the material speak to you" and "getting a feel for the organism," which in her case is maize (McClintock, quoted in Keller, 1982, p. 599). Keller (1983) used the term "super-seeing" (Cixous, 1979) for this manner of investigation and explained that it occurs when one's eyes can no longer differentiate themselves from the entity seen.

The involvement of the researcher in one's research facilitates the study of phenomena in context. To understand and interpret the functioning of the parts one must understand and be aware of the context in which they function (Bleier, 1987). Examining phenomena in context permits one to include in the data otherwise inaccessible items such as historical contingencies and situational factors or distinctions (Gergen, M., 1988; Griffin-Pierson, 1988; Wallston, 1985).

Meyer (1988) formalizes the examination of phenomena by defining two divisions of context: material and normative. The material context includes: (a) the distribution of scarce resources such as time, money, space, discretionary power, and schooling among different groups in society; (b) the possible consequences of this distribution to the groups or relations under study; and (c) the formal hierarchies involved. The analysis of the material context provides a foundation upon which the actions and interpretations of groups or individuals can be assessed and it sets a baseline allowing for the more accurate evaluation of the partial nature of research questions and the limited generalizability of results.

The normative context examines the cultural and historical setting of social actions in order to illumine the social pressures involved. An awareness of the cultural norms of the group(s) under study provides a template. Group and individual actions can be assessed as conforming or as counter-normative. According to Hubbard (1988) the feminists' insistence on the contextualization of phenomena constitutes a major contribution to scientific inquiry. She goes on to say that it is absolutely essential if we are "to understand nature and use the knowledge we gain without abusing it" (p. 10).

The examination of the context also encourages conscious explication of the value orientation of the research. In fact, it opposes the "value-free" characteristic of traditional scholarship (Heide, 1985). Value conscious research requires one to examine one's own context to make explicit one's values which will, of necessity, influence the pursuit of the inquiry (Griffin-Pierson, 1988; Jacklin, 1987).

In brief, feminist scholarship has sought to avoid: (a) fragmentation of knowledge that can weaken thought; (b) specialization that separates from wholeness; (c) technical "reasoning" that hides the unmeasurable qualitative processes of life under its relentless pursuit of quantification; (d) theorizing and generalizing phenomena without concrete applications; and (e) distancing oneself from real people so much as to be irrelevant (Heide, 1985).

Christ (1987) proposed a model for feminist scholarship that she calls the ethos of eros and empathy. She wrote:

> The ethos of eros and empathy reminds us that the root of our scholarship and research is eros, a passion to connect, the desire to understand the experience of another, the desire to deepen our understanding of ourselves and our world, the passion to transform or preserve the world as we understand it more deeply. The ethos of eros and empathy reminds us that one of the goals of our scholarship is empathy, a form of understanding that reaches out to the otherness of the other, rooted in a desire to understand the world from a different point of view. (p. 58)

This ethos of eros and empathy appears to pervade the entire process of feminist inquiry from question generation through data-gathering, analysis, and conclusion.

When examining a phenomenon, feminist inquiry into social processes has revolved around political concepts, such as power, authority, autonomy, liberty, and equality. Often this involved scrutinizing male dominance, "the most pervasive and tenacious system of power in history" , in order not only to expose its underlying assumptions, but also to aid in the creation of a construct that begins and ends with genuine female concerns and ideals (MacKinnon, 1987, p. 137).

Bernard (1987) and Biklen and Shakeshaft (1985) believe that, in order to do so, women must become the center of inquiry, a step that effectively will deconstruct the errors about women generated by traditional research. Harding (1987) agreed with this and added that, only by initiating problematics from the perspective of women's experiences and then using these experiences "as a significant indicator of the 'reality' against which hypotheses are tested" (p. 7) will scientific investigation be on the road to destroying the myths and tacit assumptions that work to maintain the current imbalance of power (DuBois et al., 1987).

The study of women from the perspective of their own experiences is proposed, not as the creation of a new privileged perception, but as the creation of a parallel perception which, in combination and cooperation with the existing one, can lead to a more complete understanding of reality. This study is new because it creates women as a category unto themselves rather than in relation to men (Griffin-Pierson, 1988). Numerous feminist researchers see in this form of study a defining of women as women and feel that only thus are we able to reveal for the first time what women's experiences are (Bart, 1985; Belenky, Clincy, Goldberger & Tarule, 1986; Foss & Foss, in press; Gilligan, 1982; Kelly-Gadol, 1987; Maher, 1985; Schaef, 1985). Feminist inquiry thus insists on the significance of studying ourselves and "studying up," instead of "studying down"--a view that "is partial and perverse" (Hartsock, 1987, p. 159). Pragmatically, women must "have an equal say in the design and administration of the institutions where knowledge is produced and distributed" so that social justice may be fully established (Harding, 1987, p. 7).

Feminist research has espoused methodological pluralism: it remains open to new methods of inquiry (Wallston, 1985). It remains open to new questions or to the reformulation of old ones. This openness allows for the shaping of new methods of inquiry which, in terms of feminist methodology, are a function of the question and not its determinant (Biklen & Shakeshaft, 1985; Wallston, 1985). Moreover, feminist methodology includes at least two major areas of thought: feminist empiricism and feminist standpoint research. Feminist empiricists believe that the inadequacies of the traditional methodologies may be overcome if we increase the number of variables studied, increase the array of hypotheses subjected to testing, and obliterate the value biases (Gergen, K., 1988; Harding, 1989a, 1989b). Feminist standpoint researchers, on the other hand, believe that only by detailing women's experiences can we achieve a more accurate view of reality (Harding, 1989b).

In conclusion, feminist investigators have attempted to alleviate the biases found in traditional research by rejecting extant prejudices and envisioning the elimination of any dominance based on sex, race, income, religion, age, ethnicity, and/or sexual preference. This type of research has involved: (a) contesting accepted paradigms that function to validate the existing social structures; (b) facilitating access to the making of facts to a wider spectrum of people; (c) examining important questions that have not been generated by a social process that is dominated by the experts in fact making;[2] (d) involving the public in the validation process; and (e) building accountability into all stages of the fact-making process (Hubbard, 1988). In a word, feminist methodology is a "dynamic process of unthinking, rethinking, energizing, and transforming" existing reality (Bush, 1983).

Grounded Theory

Two sociologists, Glaser from Columbia University and Strauss from the University of Chicago, developed a new qualitative methodology in the 1960s known as grounded theory (Glaser & Strauss, 1967). They envisioned a paradigm-transcending methodology that went beyond extant theories and preconceived conceptual frameworks in search of new understandings of social processes in natural settings, a methodology in which the theories would arise out of the data rather than out of paradigmatic research that uses existing models or theories and obeys laws inherent in the model (Hutchinson, 1986). The key idea was discovery. This theoretical stance is particularly suited "for research which must be conducted in the dynamic environment of most field settings" (Swanson & Swanson, 1990, p. 46).

According to Hutchinson (1986), George Mead and American pragmaticism formed the philosophical foundation for grounded theory. Its sociological roots, following Bantz (1983) and Lewis and Smith (1980) were provided by Herbert Blumer and symbolic interactionism (a branch of naturalistic research). Whereas, traditional scientists begin with problems or interests within theoretical concerns that result in "objectively" identifying and examining a situation that is "out there," static, and available for study (Stanley & Wise, 1983), symbolic interactionists, stated Hutchinson (1986), believe that "human reality is not simply 'out there' awaiting scientific study. Instead reality is socially and symbolically constructed, always emerging and relative to other facts of social life" (p. 51).

Participant observation, interviewing and document analysis--the principal data collection procedures in grounded theory research--permit researchers to immerse themselves in the dynamically changing social process under study. Blumer (1962) wrote:

> To try to catch the interpretive process by remaining aloof as a so-called 'objective' observer and refusing to take the role of the acting unit is to risk the worst kind of subjectivism--the objective observer is

> likely to fill in the process of interpretation with his [sic] own surmises in place of catching the process as it occurs in the experience of the acting unit which uses it. (p. 188)

Through this immersion the researcher is able to discover and conceptualize the essence of specific interactional processes by identifying patterns of individual experiences as they are observed and/or recounted. From these identified patterns researchers can formulate judgments and appraisals. Consequently, grounded theory is seen as a form of social criticism (Hutchinson, 1986).

Swanson and Swanson (1990) wrote that "grounded theory is particularly useful in the generation of theory because it assumes that emerging theory is grounded in the research data rather than forcibly relating grand theory" (p. 43).

Martin (1978), Blase (1982), and Gehrke (1981) considered grounded theory a good method to use in examining education. Martin (1978) stated that, because many educational theories were generated in a vacuum-like, abstract environment, many of their findings were framed and limited. Theories originating in grounded theory were grounded on the environment that birthed them and therefore were freer and more dynamic than their counterparts. A validity check of these procedures is achieved by conducting a study over an extended time period and by searching for negative or contradictory data within the study. These data then become part of the knowledge base that continually is used to adjust the dynamic theories or judgments emerging from the study.

One criticism leveled at grounded theory studies is that they are not easily replicable since they are studies of dynamic systems with dynamically formulated findings. Therefore, they may not be considered reliable. This point may be somewhat irrelevant since the purpose of theory generation is "to offer a new perspective on a given situation" (Hutchinson, 1986, p. 59).

Current Study and Methods Used

The present study examines the experiences of women in a research-based university (hereafter called "University") computer science department in the Northwestern United States during the 1980s. Its purposes were to: (a) accurately recount the experiences of female undergraduate computer science students, placing emphasis on the elucidation of barriers that confronted them and (b) thoughtfully present suggestions for a computer science program that will attract and retain female students.

Formulation of the Question

Feminists are asking questions and seeking answers that are different from the conventional ones. We are not looking at women in relation to men, as generally has been the case in traditional research. Rather we are formulating questions about women themselves in order to get to the heart of our problems (Biklen & Shakeshaft, 1985). We are conducting research that will provide "explanations of social and biological phenomena that women want and need" (Harding, 1989b, p. 27). We are an oppressed group. We are asking how to change the existing conditions that tyrannize us. We are trying to illumine the forces, beyond our control, that shape our world. We are attempting to find ways to neutralize these forces. In a word, we are striving for our emancipation, growth, and development (Harding, 1987).

"The questions that men have wanted answered all too often have arisen from desires to pacify, control, exploit, or manipulate women and to glorify forms of masculinity by understanding women as different from, less than, or a deviant form of men" (Harding, 1989b, p. 27).

Feminist research is biased, as biased as conventional research. The difference lies in that feminists do not hide their bias under the cover of objectivity. Admittedly, question-generation--the choice of the problem to be investigated and the approach used to study it--is particularly vulnerable to bias (Jacklin, 1987; Harding, 1987). How these questions are conceptualized and operationalized depend, of course, on the views and interests of the investigator (Parlee, 1975). Nevertheless, because the background of the formulation of the question is made explicit, the reader more accurately can interpret the findings of the research effort.

Therefore, the feminist researcher

> names the eros, the passion, the desire--to understand, to connect, to preserve or change the world--that inspired her or his research. This does not mean that the scholar's work is narrowly personal, solipsistic, or self-indulgent, terms taken from the ethos of objectivity. But it means that she or he names the interests that inspired and to some extent shaped her or his research. (Christ, 1987, p. 60)

The question, "Why do so few women complete the undergraduate study of computer science?" emerged from my experience as a student in the computer science department of the University. It was born from observing dwindling numbers of women in my classes and from conversations with female classmates. It was fed from day to day hearing some of them say, "I love computer science but I can't take this . . ." It grew stronger from experiencing frustration and the constant menace of failure and came to fruition in a burning desire to increase the number of women graduating as computer scientists.

Data Collection

The focus of the data collection was to (a) identify existing characteristics of the environment in the University's computer science department during the 1980s, perceived by women as alienating, discouraging, or frustrating and (b) provide a comfortable environment for women in order to answer the question, "Why do so few women complete the undergraduate study of computer science?"

The principal data used were women's experiences: My own, as an undergraduate student for 4 years and then as a graduate teaching assistant for the subsequent 3 years in the computer science department at the University, and the experiences of 22 female computer science students at the same University. My experience and that of my colleagues were gleaned from interviews I conducted individually with these women for varying amounts of time--one-half hour to three or four hours. At the time of the interviews (1987), these women were either currently enrolled as majors or minors in computer science at the University, had graduated with a degree in computer science, or had changed majors. The interviews were recorded and transcribed for ensuing analysis.

During the interviews, we recounted our experiences in computer science beginning with the first required class in which we enrolled until the time of the interview, until the decision to leave the study of computer science, or until graduation. The interviews were unstructured to enable the women to speak in their own voices. The women were assumed to be reliable witnesses of their own experiences (Biklen & Shakeshaft, 1985; Stanley & Wise, 1983). In accordance with grounded theory, rather than determining what should be included in the data I allowed ideas to "emerge" from the interchange. These interviews could more accurately be termed conversations for I involved myself in the discussions, another tenet of feminist methodology (Oakley, 1981). However, the majority of the time, I functioned as an active listener to each participant as she shared her story. If during our conversation, a woman had not mentioned common themes previously discussed by other participants, I would ask question her about them. The questions I asked revolved around the following aspects of the computing environment: (a) first impressions of the computer laboratory and of the first class in computer science; (b) descriptions of the classroom and laboratory environments; (c) reasons for studying computer science; (d) reasons for continuing or terminating the study of computer science; (e) descriptions of situations that evoked feelings of discouragement and frustration and/or encouragement and support; (f) description of hackers; and (g) characteristics of a program they could envision that would attract and retain female students.

Presumptions inherent in the traditional research approach are that the researcher is more knowledgeable and competent than the subject, expects to have complete control over the way in which the study proceeds, and never shares her/his own views with subjects during the research lest there be "contamination" of the results (Gergen, M., 1988). The hierarchical relationship between participant and researcher resulting from these presumptions was consciously rejected in this project.

I chose instead to rely on feminist methodology and grounded theory. Thus, the women taking part in the study did so, not as subjects, but rather as partners with the researcher in a cooperative effort. The participants' ideas and suggestions were valued and incorporated into the study. Some of my orienting premises were questioned and subsequently altered because of their input. I did not attempt to be removed or impersonal in my interactions with the women, but listened carefully to their thoughts, feelings, and intuitions about their experiences. If they asked me questions, I freely shared with them experiential information as well as findings from the literature.

To provide a check on this experiential data, I gathered enrollment data for required computer science courses at the University from 1980 to 1987. The categories of data included information about students, courses and teachers. Foreign students' records, whose social security numbers began with 999, were eliminated from the database. Individual records contained a student's social security number, sex, course number, term and year enrolled, grade received, as well as the sex of the professor teaching the class. Although the proposal for this dissertation did not include this data collection, the researcher, following the guidelines of feminist research that advocate methodological pluralism, added these data and their analysis to provide a more complete picture.

Analysis

The following principles from feminist methodology and grounded theory guided the analysis of this project: (a) the inquirer and the overt subject matter were placed on the same critical plane (Christ, 1987; Foss & Foss, in press; Harding, 1987; Hubbard, 1988; Jacklin, 1987; Maher, 1985; Meyer, 1988; Oakley, 1981; Stanley & Wise, 1983), a process called "bracketing" in grounded theory (Berger & Kellner, 1981); (b) the researcher's assumptions about "class, race, culture, and gender," as well as her beliefs and behaviors were placed within the framework of the picture that she was attempting to paint (Harding, 1987, p. 9); and (c) the impact of the research findings on society was acknowledged (Jacklin, 1987; Meyer, 1988).

Moreover, in accordance with grounded theory, the analysis served one or more of the following purposes: to initiate new theory and to reformulate, refocus and/or clarify existing theory (Blase, 1982; Denzin, 1970; Gehrke, 1981; Hutchinson, 1986). Further, in agreement with procedures outlined in the same theory, the interview analysis involved identifying a "core variable" using a minimum of three levels of examination (Glaser, 1978; Hutchinson, 1986). First, the interviews were searched for words and phrases of action and/or location in women's experiences. In this step, I used the "awk," "grep," "deroff," "sort," and "vi" utilities of the UNIX operation system. Secondly, the words and phrases thus arrived at were grouped into categories. Finally, the categories were structured to provide the theoretical constructs for the proposed emerging theories. The "core variable" tied all of this together by being inextricably woven throughout the categories, properties, and dimensions of the emerging theory.

The analysis of the enrollment and achievement data consisted of comparing females' and males' enrollment numbers and achievement levels in computer science courses. I sought to answer questions such as: Were fewer women than men enrolled in beginning computer science courses? Did more women than men drop out of computer science courses? Was there one particular course that seemed to cause women to drop out of the program? Did women achieve higher grades in these courses than did their male counterparts? The SPSS statistical package was used to provide answers to these questions.

In summary, this research project attempted to: (a) describe what existed, "how things were" for women enrolled in computer science at the University; (b) analyze why this reality existed; (c) hypothesize and make recommendations about what changes should be made in order to increase women's enrollment and retention in computer science.

Notes

[1]Throughout this dissertation I include myself in "women" and refer to us as "we."

[2]This is a continuing obstacle to feminist research because the resources that are needed to conduct research are controlled by these "experts" in fact making.

CHAPTER IV

FEMALE UNDERGRADUATES' EXPERIENCES WHILE STUDYING COMPUTER SCIENCE

Introduction

I became concerned about the plight of female students in computer science when I was pursuing a B.S. degree in this field at the University. Often I felt acute discomfort as a woman in this predominantly male environment. Throughout my involvement in this program I observed my female classmates' increasingly dwindling numbers. I wondered why they left and I felt compelled to do something to reverse the trend. As a step in this direction, I interviewed twenty-two female students who were or had been enrolled in required courses for undergraduate computer science majors at the same University. The women's experiences, gleaned from the interviews (described in chapter three) and combined with my own, form the content of the first section of the present chapter.

The women interviewed ranged in age from 20 to 45 years: thirteen were in their 20s, seven in their 30s, and two in their 40s. These women were chosen because they reflected the mix of ages of the women in my classes throughout the program. They were among typical college students in that they took more than four years to graduate from college and had to work to help defray educational expenses and to support themselves (Wilson, 1990). More than half of the women were re-entry students who were changing or beginning professional careers.

Most women interviewed had been near the top of their class in high school and were more accustomed to receiving A's than anything else in previous school work. In most cases, they enjoyed and excelled at high school mathematics and generally had studied it for three to four years before entering college. Most of them had not studied secondary level computer science and only a few had used a computer before beginning their formal undergraduate study.

These women were drawn to study computer science for multiple reasons. Most had liked mathematics in high school and felt attracted to the study of computer science because they believed the two sciences were closely related, or they had been casual users of computers and had grown curious about these machines. Some of them were interested in learning how they could create new software rather than to operate programs built by someone else. Many had been encouraged to attempt the study of computer science themselves as they observed a female, sometimes a close friend, who was enrolled in studying it. Still others wanted to live a comfortable life and viewed a degree in this area as a suitable vehicle for earning sufficient funds to do so. They wanted the freedom to work in alternative working environments, such as the home, and with flexible hours, for instance early mornings or late evenings. Some aspired to acquire expertise they could use to further the interests of peace rather than the interests of war. A few were artists and wanted to use the computer as a tool in drawing, painting, weaving, or beading. Others were writers and believed they could support themselves by writing about the computer. In one way or another, these women had been drawn to the study of computer science, had converged at this University, and had become the participants in the drama of my research with me. Like them, I had chosen computer science for similar reasons and had undergone some of the same experiences while studying it.

Each woman's unique story provided a wealth of information from which it was possible to elicit many commonly shared impressions. Most women experienced similar feelings, events, and interactions whether or not they completed their undergraduate studies in computer science. Many of them felt discomfort and pain while recalling their experiences. Nevertheless, they were articulate, personable, bright, caring, and had a strong desire to contribute to the purpose of this research, namely to make the study of computer science more accessible to women.

To arrive at an understanding of these women's experiences, I first used several utility programs in the UNIX operating system to search the interviews and produce an alphabetical listing of the words found in them. Next, I selected from this list words that referred to physical locations, significant persons, actions, events, and feelings associated with the process of acquiring a degree in computer science. Then I determined the number of women who had used the above selected words and the number of times they had used them. Further I compiled a final list of relevant words. Subsequently, I created collections of pertinent interview excerpts containing each of the relevant words in order to have them in context. Finally, I grouped these collections into the subject areas around which I organized this chapter.

This first section of the chapter is divided into the women's descriptions of and feelings about the following components of their learning experiences: (a) the Computer Science Department and its operating procedures; (b) the learning environment of the classroom, including the format and content of teachers' presentations, as well as student-teacher classroom interactions; (c) the computer laboratories in which students prepared their machine-based assignments; (d) textbooks; (e) evaluation procedures and instruments, including assignments and tests; (f) student-teacher interactions outside the classroom; and (g) student-

student interactions.

The second section of this chapter provides information gleaned from the 1980-1987 enrollment and achievement data that was collected from the Computer Science Department at the University. The results from the analysis of this data add different, yet supporting, details to the picture of undergraduate female computer science students' experiences obtained from individual interviews.

Women's Experiences Derived From The Interviews

Computer Science Department

"The first day I stepped into the Computer Science Department and asked questions I felt as though I didn't have the combination to a safe and they were not going to give it to me." This woman's feeling was shared by most women as they recalled their first contact with the department. The requirements for enrollment in the department were often changed and often seemed to exist in the form of rumors rather than in the form of concise printed statements. The ones that did exist in print appeared arbitrary and subject to interpretation.

Students' did not feel that they belonged in the Computer Science Department. This feeling perhaps resulted from not being allowed to declare themselves as computer science majors until they had satisfactorily completed all required computer science courses at the 200 and 300 level, as well as one year of calculus and another of discrete mathematics. Satisfactory completion meant receiving at least a B in the course. The courses were sequentially organized so that one had to receive this grade before proceeding to the next course in the series. If students received a C or lower or dropped the class and wished to repeat it in order to meet the B requirement, they could not register for it until first-time enrollees had opportunity to enroll. In addition, after waiting in long lines during registration, students were not trusted to enroll in the appropriate course. Their name had to be located and previous grades verified in the "black notebook"--"a mysterious and terrifying record" of their names and past deeds--before they were allowed to enroll.

The women had not expected to encounter these difficulties in their learning environment. "It was bizarre. It was so different from anything I was used to," one woman said. From the start, and throughout their involvement in this program, they faced circumstances they had not met in previous schooling experiences and, in time, began to question whether "the emphasis of this program was education." Most of them came to believe that its "emphasis was making students jump through hoops and eliminating as many of them as possible." This threat of elimination--an always present menace--persisted throughout the entire program even until the last two required classes for majors.

"I don't think the Computer Science Department is really open to what students' interests are." "Instead of the department being supportive, the department is your adversary."

People in the Computer Science Department did not seem happy to see these women in computer science. Some of the women felt unwelcome simply because they were women. One woman recalled:

> I was told I was new here, I didn't know how it goes here. They wouldn't tell me . . . It was like no matter what you do, you have to understand you are a woman. 'We are not real happy with you being here.' That is the way I felt from the day I first walked into that department until today. It has not changed.

The implication was that her femaleness was the source of her difficulties. Later, while observing the students who walked the hallways and reading the names of the professors and graduate teaching assistants on their office doors, glancing at the magazines in the lounge and the announcements on the bulletin board, the women became aware of the "overwhelming" predominance of men. Though some of them said "I expected it," they still found themselves very conscious of their difference. They wondered, "Am I in the wrong place?"

Classroom Learning Environment

Introduction to Computer Science, CIS 201, was the first required class for majors. During the seven years of the study CIS 201 met in huge amphitheaters that typically were filled with students. For the women, the shock provided by the large number of students in the room was heightened by the discovery that very few of these students were female. Many of the women reported feelings of anxiety at this finding. They said things like, "it really creates a different attitude when there are so few women." "There is an essence here that is upsetting to me--it is a general attitude about women." "I can distinctly remember that programmers were 'he's,' feeling very left out." "I felt extra self-conscious because I was a women." "By attitude I mean, because I was a women there was definitely a sense coming from the teacher and the other people I was working with that I could never be as good as the men." One women summarized these feelings as follows:

> The men were in the majority. I really did get the sense that if I were a man it would be very, very different for me. It would have been different for me in education, it would be different for me in the workplace. In some ways I don't want to be a man. In some ways my road would be a lot easier because of the relationship that men have with men. That is the status quo. I sometimes feel a little angry about knowing that that difference is there.

The first day in class offered students a series of surprises. To begin with, they were greeted with the introductory remark about the inability of the Computer

Science Department to service most of their needs. "We don't have professors. We don't have hardware. We don't have the resources to accommodate you; therefore, we must weed you out. Only one-third of you will be able to advance to the second class."

Another surprise came up when the instructor (rarely a professor) asked students to raise their hands in case they did not have any previous experience with computers. Most of the women did not have prior experience but some of them were afraid to raise their hands. As one said, "I wanted to know what was happening before giving out that information." These inexperienced students, usually less than 10 percent of the class and often female, were then reassured that previous experience was not required, a condition agreeing with the formal requirements in the bulletin.

But there seemed to be "an official set of prerequisites and another set of unofficial ones. The unofficial ones you weren't aware of until you were in class." The women specifically had been told, in compulsory advisement meetings with computer science instructors during registration, that they did not need other computer science classes before this one. Apparently, however, this was true only in theory. In practice, as they found out, 90% of their classmates had previous experience which, in many cases, went beyond mere computer literacy. In fact, some of them already were employed as programmers. Because most students in the class already were acquainted with basic concepts and terminology, these were omitted, or discussed only cursorily, by instructors. In time, it became obvious that, though not required, previous programming experience was expected.

This practice placed the majority of the women at a clear disadvantage. Denied the foundation upon which to build new knowledge--a crucial process in the learning of computer science--they began to wonder what their chances of success were. "What would have helped me to stay would have been to have prerequisites quite well defined for the courses." One woman said, "I got a D in that course. I had never had a D." Another said, "I felt like an outsider." Another said, "I didn't understand even how to turn on the computer." Still another recalled:

> There was a little Taiwanese girl that was sitting next to me for a while in one of the classes. The teacher made up his own little assembly language for beginners. He taught it in class. He spent a total of 4 minutes teaching us this assembly language. We were to write a little program. This little girl was just beginning. She was totally lost. She got a zero on her assignment. She quit computer science.

I believe the discomfort and difficulty experienced in teaching a subject to persons with such disparate qualifications is surpassed by the frustration endured by students who are inexperienced in computer programming in such a class.

Some of the women in the above group failed and repeated this first class. Others repeated it because they felt they did not have a sufficient grasp of the information it covered. The successful ones were able to get ahead only at the cost of preparing 20 to 30 hours each week for this four credit class. Many said that the material covered in the first class "was fully understood only upon completing the second."

The few women who had previous computer programming experience found the first class to be "understandable and challenging" and experienced a "refinement of previously acquired skills." However, as was the case with the other participants, they also found the class to be intense, stressful and isolating. The interviewees suggested that these conditions resulted from discouraging students "to interact and work with each other" and from forcing them to compete for a limited number of acceptable grades in order to stay in the program.

Instructors, most of whom these women remembered to be men, used the lecture format with accompanying overhead transparencies throughout the undergraduate required courses. This method facilitated the coverage of vast amounts of information, a large percentage of which was unfamiliar to the women. The female students interviewed felt that "we were on a schedule and had to cover particular topics on specified dates. If we were unable to complete the topic, we were responsible for searching out the idea and finishing it ourselves. We felt like we were numbers."

Another said, "I felt subhuman when I took computer science classes."

Most of the women described the computer science classroom as "a real shock, especially the affective part." One women explained, "The change in tone, the change in tenor was really hard for me to get used to. I couldn't understand what the instructor was saying a lot of the time. I began bringing a tape recorder to class because it was like a foreign language to me. I had to listen to it again and again and again. Even the pacing of the words was just so foreign."

Familiar English words were used in unfamiliar contexts leaving the women confused and frustrated. The unfamiliarity and the quantity of the materials lectured upon were not the only obstacles that made this course difficult to understand. Some of the professors and many of the graduate teaching assistants used English as a second language. In these cases, the transfer of knowledge appeared to approach the lower end of the scale. It drew dangerously close to zero when the instructors mixed computerese with their English. This state of affairs caused major problems for the women. "I just could not figure out what they were saying," recalled a woman, expressing a general feeling. Moreover, when the women tried to use the problem solving sessions, taught by graduate teaching assistants to alleviate the confusion or lack of clarification encountered in the lectures, they found themselves even more confused.

Few examples were given in the lectures to explain the concepts presented. One woman summarized the participants' viewpoints when she stated, "I needed more examples. There were not enough examples given." Others complained of the technical and mathematical orientation of the examples. Decoding of the symbols and mathematical concepts used in them required mathematical training beyond that specified as prerequisites for the courses. Additionally, many examples were taken from contact sports, mechanics and construction, domains unfamiliar to most women. Examples from "business or insurance" invariably pegged those in "decision making positions as male and those in support positions as female." In some cases teachers used "incorrect, incomplete and confusing examples" and assumed a defensive posture when asked to clarify them. They would "sidetrack the question," or be "visibly annoyed," or "call the student stupid for not understanding."

Teachers invariably referred to programmers, systems analysts, software engineers and computer scientists as males. None of the women could remember hearing a computer professional referred to as female. One of them recalled asking quite loudly, "Well, can I be a computer programmer too?" and having her question ignored. Another woman remembered occasions in which a teacher brought to class the latest reports of sex differences research which stated that females were not as capable in mathematics as males. The intent was, she believed, "to connect mathematical expertise with computer expertise and thereby give the message that women were less capable than males in computer science."

Most instructors discouraged question asking, and the women noted that few questions were asked in the 200- and 300-level courses. They hypothesized that the size and atmosphere of the classes contributed to this paucity of class involvement. Moreover, they could not recall a single instance in which a student without previous computing experience had asked a question. Furthermore, rarely could they understand the questions asked: "Had I missed something in my reading or in the lecture?" "What was it I needed to know in order to understand the question?" "How does the question relate?"

Only two of the women interviewed reported having asked questions in class. These two women felt that they had paid for this classroom instruction and thus were "entitled to ask questions even if I might appear 'stupid.'" One of them felt that she had gained respect from teachers for taking this stance. The other, though she felt as strongly about her need and right to ask questions, experienced ridicule from her peers and saw teachers visibly sigh and become frustrated in response to her question asking.

Most questions generally were asked by older males with computer knowledge, who sometimes appeared to be trying to wrest control of the class from the teacher. They tended to ask questions about specific hardware or software or other peculiarities beyond the scope of the course content. Their questions rarely were helpful in clarifying the topics under discussion. Many women felt "intimidated" by these questions: they served to silence those students with less computer experience.

Most of the women kept silent throughout their entire tenure as undergraduate students. They were overwhelmingly "afraid of being thought stupid" and of "revealing how little they knew." They recalled several occasions when professors ridiculed students who asked questions the teachers did not view as bright or did not like. "If a student, who raised their hand and asked a question, was belittled by the teacher throughout the whole lecture then most people had few questions after that."

Questions posed by the teachers most often were directed at male students. The women felt that "teachers tended to cultivate the male members of the class more than the females." If women and men raised their hands at the same time in response to a general question, "I think that the men usually were picked first," one woman said.

The general opinion of all participants was that computer science courses were poorly taught. The instruction often was confusing, ambiguous, and unhelpful.

The environment was hostile and discouraged learning.

Computer Laboratories

The students' frustrating experiences in the classroom were further exacerbated in the computer laboratory. Each course in computer science required several programs to be written on specified hardware using a particular computer programming language. Students were not expected to nor did most of them have the hardware and software required for the courses; therefore they were obligated to utilize the University's computer laboratories. This required adaptation to an environment that most of the women found to be even more intimidating than the classrooms'.

The beginning students' introduction to the laboratory evolved from a few instructions given during the lecture to a 50-minute hands-on--"get acquainted with the computer"--session. "The instructions given in class often were in error." They probably were "appropriate to the hardware the instructor was working on" but did not apply to the hardware the students were using. Computer commands are cryptic and make no logical sense. Therefore, it was nearly impossible for a beginner to deduce them logically. Moreover, in order for the commands to work they must be followed with exactness. The slightest error in the instructions given, leading to the misplacement even of a punctuation symbol, could, and often did, cost a new student hours of trial and error to isolate the omission or error in those instructions. Teachers did not seem to have "a realistic idea of what you had to do."

The time required for the initial period of acquaintanceship with the computer was phenomenal. One woman described it as follows: "I felt that I couldn't have anything else in my life. I had to give totally of myself." Most women found that they were spending 15 to 20 hours each week in the computer laboratory in the first class. This time did not include the time needed to study the textbooks, class notes, or written assignment preparations. Nor did it include the time spent waiting in line to gain access to a computer. A wait of 2 or 3 hours to get a machine was not uncommon. However, the returns for this large investment often were disproportionately small. Not uncommonly, one could spend hours locating a missing semicolon only to find that the useful information gained from this search was negligible.

The women, who did not have previous experience with computers, found the laboratories to be disorienting. The absence of connections to prior knowledge left them feeling "stupid," "tense," and "anxious." They were "afraid to experiment for fear the computer would sound an alarm or erase existing administrative data or alert someone somewhere," who would come running into the room shouting at them for their stupidity and the damage their exploration had caused. They were terrorized by the thought that the computer might keep a record of their attempts and make it available to those in authority who could then see how little they really knew, or, worse yet, provide the authorities with the documentation needed to eliminate them from the computer science program.

These laboratories caused all of the participants much frustration. Some women had purchased their own computers to escape from these environments. In so doing they gave up access to assistance from laboratory assistants. Not a great loss perhaps, since most of the women found these persons, primarily men, to be rather unhelpful. They often "did not understand the assignments, the hardware, or the programming language" a student was using. Since the assistants were either advanced undergraduate students further along in the program or graduate students, frequently one would "find them involved in their own work during their hours on duty." One easily could get the impression that "they were more interested in working on their own work than in helping students in the laboratory." Therefore, one felt uneasy about interrupting them in order to ask for help.

Few lab assistants were women. However, one woman noted that "when female lab assistants were doing the explaining they tended to explain why. They tried to give an understanding." Whereas when male consultants responded to the women's requests for help, they most often "took over the keyboard and fixed the problem without a word of explanation." When the consultants were asked for an explanation so that the student could fix the trouble herself were it to come up another time, frequently they condescendingly brushed aside the request. More often than not, women "felt stupid when asking for help" and consequently surfaced from the interactions with consultants more hesitant than before to explore on the machine and to ask for help.

The women believed that computer science reflected a male orientation and found evidence for it in the language they were required to use in communicating with the computers. The commands, words that form a part of the operating system language to direct the computer to perform actions, appeared to be coming out of the mouths of combat sergeants. In addition, expressions commonly heard sounded the same: "Execute" the program, "kill" the process, "abort" the job, set up a "flag," type in your "password," and "my program bombed." Moreover, descriptions of the computer's operational status reflected males' sexual experience. Thus, the machine was "up" when it was operating and conversely it was "down" when it was dysfunctional. Furthermore, the logical organization of a computer system, including its filing and menu systems, was hierarchical.

Students in the 200- and 300-level required computer science classes used computer laboratories in the Computing Center. These labs, the women felt, were filled with tension. "Anxious people, crowded into unventilated, smelly, hot rooms, worked frantically trying to beat the deadlines." One woman described this tenseness as follows: "People were angry there, they slammed books, they hit the keys on the keyboard a little too hard, they said choice words or expressions, and they heaved heavy sighs." Another said:

> I always thought they smelled like locker rooms and I thought that was due to the panic level that was going on in there. It usually seemed like people were all in there panicking individually and hacking on the machines. It was never a relaxed situation where people were just logically working through problems.

The laboratory used by the 400-level classes was located in the Computer Science Department. It was not staffed with consultants or laboratory assistants except for an occasional systems programmer who would wander through while performing work on the system. The women found this lab particularly distasteful. Except for one year in which I was one of them, the systems programmers were all men. One woman described them as "men that smelled bad and dressed in filthy clothes: they looked like they hadn't washed in a month." This lab was recalled by one woman who stated:

> I had never been in a place that stunk as bad as that lab. How do the faculty expect people to work in that? Don't they care about the people who work in there?

> Don't they care about the image they give to people who come here? They seem to have no sense of the real world.

The systems programmers were as graphically described as the laboratories in which they worked. Many of the women defined them as "Big Gulp drinkers who lived on twinkies. They were nice people but had no social skills. They couldn't hold a conversation. They shot dart guns at night in the hallways and just acted bizarre." Some women called them "hackers"--members of the "in crowd" of computer science.

Some laboratories had walls constructed on long tables to isolate each computer and its user from their adjacent neighbors. One woman said, "I felt cramped sitting at the little cubicles. It was uncomfortable. You felt really isolated." Another said, "Everybody around seemed to know what they were doing. You felt that you couldn't talk to them." Still another said, "I felt like I could cut the air with a knife. I felt like the whole place was an assault on my body. You were sort of required to become as neutral as the machine . . . After a while you really felt like you were in a jail cell."

Frequently, students found that they needed to work in the laboratories until 4:00 a.m. when the Computing Center closed or all night in the upper division laboratory. Some women reported receiving pornographic messages late at night on the screens of their computers. Others encountered frightening situations upon returning home at day-break. However, even though most women were afraid, they felt that they were required to work these late hours in order to survive the program.

Textbooks

The women used strong descriptors when they talked about undergraduate computer science textbooks. They found most of these books to be "worthless," "atrocious," "mediocre," "sexist," "impossible to learn from," "undecipherable," "intimidating," "not worth beans," "really bad," "not good," "difficult," "challenging," "very intellectual," "very technical," "frustrating," "terrible," "useless," "unable to explain anything well," "poorly written," "unclear," and "confusing and filled with mistakes." Only, occasionally was a textbook described as "excellent," "easy to follow," "easy to use," or "fairly good."

Generally, the women found the content of a textbook chosen for a specific class to be irrelevant to the information presented in the lecture. Moreover, they questioned the appropriateness of the level of information in the textbook. For example, professors described a particularly difficult textbook, used in a first year required course, as a graduate-level book. "The first 16 pages made sense; after that, students must really dig for the information needed."

The majority of the women felt that the textbooks had not helped them learn computer science. The books contained few graphical illustrations of ideas and did not present theoretical concepts in a clear, straightforward manner. Textbooks, as well as lectures and other verbal and written communications, appeared shrouded in mystique. Concepts were made abstract, vague and mysterious. Amazingly enough, however, these concepts assumed simplicity when understood. As one woman put it, "I was surprised over and over and over again to discover the exquisite simplicity" of a concept when it was stripped of the shroud.

Moreover, computer science textbooks referred to all computer professionals as males. The introduction of the graduate-level beginning textbook, referred to above, marked computer professionals as males 11 times. Another textbook included in its preface the following declaration: "The usage of masculine nouns and pronouns is intended to include women." This sort of inclusion, however, did not seem clear enough. Women simply "did not feel included." Instead they expressed feelings of self-doubt, decided that "it's the way things are," or felt angry. A rare, recent textbook included women as computer professionals. One of the women noticed this and commented that "it was the first book where the author was careful to include women by using 'he' and 'she' and depicting many women in the examples."

The examples in most textbooks "portrayed males as presidents of companies, decision-makers and computer professionals." The interviewees found "a token women here and there," but most women, represented in the scenarios, were cast in supporting roles or passive stances. Furthermore, as with the examples used in the lectures, textbook examples were chosen from domains often unfamiliar to women, namely mechanics, contact sports, physics or some types of businesses.

Evaluation Procedures and Instruments

When one moves from textbooks to the evaluation of students' achievement, as measured by written and programming assignments, midterms and examinations, one is confronted with an even less encouraging picture.

The women often discussed assignments in our conversations and described them as "extremely frustrating." The instructions for written and programming assignments, distributed in the classroom, usually were typed. Most women recall how difficult it was to understand what was being asked in the assignment after they had read it. One woman explained this phenomenon in the following terms: "The assignments were very vague. Sometimes half of the time spent solving a problem was in figuring out the specifications." To make matters worse, these specifications sometimes were changed and the alterations "were communicated to individual students in teachers' offices or they were posted in the computer laboratory." Often they were not announced in class. Therefore, students who had a computer and worked at home were at a distinct disadvantage.

One woman told of receiving an incomprehensible assignment in the 300-level required data structures course. The problem was from the field of mathematics in which she had a rich background. She had been questioning the evaluation processes used to grade her work and felt this was her opportunity to test them. She reported,

> I fabricated a solution. I concocted a book that I had taken it from, citing an author and a title. I made up an omega and put it all over the place. It made no sense mathematically; it was sheer garbage. I received all of the points for the solution and two extra points for doing an exceptional job. The author of the book I quoted was my cat.

Many women stated that teachers apparently had not done the assignments before assigning them to the students and, they believed, this contributed to the vague problem descriptions and specifications noted above. Women also questioned the manner in which a correct solution was defined. If correctness was determined by comparing various solutions arrived at by different students, how could there be equanimity considering the vast differences in students' programming abilities? This procedure easily could lead to attributing a lower than the just grade to the work of the less experienced students, particularly in cases where assignments assumed prerequisites not specified for the class.

Many women concentrated on the human-machine interface between the user and her program and the documentation explaining how the program was constructed and how the user should run it. This emphasis often was self-generated, for the "major grading emphasis was upon the construction of the program and program-machine interaction." Sometimes they spent many hours on the human-machine interface and felt frustrated that their efforts went virtually unnoticed during the grading process.

The time required to complete a programming assignment was overwhelming to all of the women. Often they spent at least 15 to 20 hours a week on programming assignments. Many hours could have been saved if the teachers had previously done the assignments and the instructions had been clearly defined and error free. One woman said,

> I found that to get through this program I had to visit office hours regularly in order to decipher the assignments. This information should have been provided for me. Frequently, it wasn't because I didn't understand concepts, it was because the assignments were so poorly written. I had to get in to their office and find out what they wanted and what was missing.

A woman summarized well the opinion of the rest of them on programming assignments when she said, "You do it on your own. You figure out what the problems are and what the typos are. You talk to people about the information needed to complete the assignment that the teacher didn't give you." She concluded, "The program was for people who were willing to struggle through the mess. The main emphasis was elimination of people. I never felt it was education."

Beginning in the 300-level classes and continuing through the senior level, students often were expected to work in groups. Groups usually were composed of two to four persons and rarely, if ever, were assigned--they were self-designated. Some women worked in groups in which they were the only woman. Others worked in groups predominantly composed of women. Still others worked in all female groups. The experienced males in the class usually stuck together and did not allow women to participate in their groups. "It was very rare for them to accept a female into their groups. That was kind of hard to deal with."

Membership in a good group was crucial to success. The grade assigned was a group grade given individually to each member. There was little monitoring of proportion of participation by group members. Teachers did, on occasion, arbitrarily give different grades. This practice was not challenged by the women to whom it happened. If a student was absent on the day groups were chosen or "if you were not chosen or if you were sitting in the wrong place," your ability to succeed in the class could be threatened. The choosing process was reminiscent of choosing teams for softball in grade school. For some students this was a painful process.

In groups in which one woman worked with several men often she assumed the role of "communicator." "They didn't want to talk to each other so they each talked to me and I, in turn, talked to the others. My main role was to take their work and to integrate it with other people's work."

In more evenly balanced mixed groups, women reported having good and bad experiences. Sometimes a woman grouped with people who didn't work and most of the work fell on her shoulders. This situation happened to some women when they attempted to assume a leadership role in a mixed group. The males, whom one woman described as "loud" and "sexist," sometimes "sabotaged groups," "publicly berated female participants," and/or "refused to do any of the work," thus placing assertive women at risk--if the project was not completed satisfactorily, she received a lower grade. One woman expressed the women's concerns about differences in group participants' problem solving methods when she stated, "Even though every book says to organize your thoughts before you start, the men sat down and started coding immediately. I found that very frustrating. I wanted to know the whole picture before I started." All-female groups seemed to be the favorite choice of any women who had worked in such a setting. They found these groups to be "supportive," "noncompetitive," and "hardworking."

Most computer science classes included one or two in-class midterms and a final each quarter. The women felt anxious and afraid when taking examinations. Even women who previously had been good test takers found that they did not know how to take these examinations. One of these women said, "They were so far out. They had nothing to do with the material presented in class." Others felt that the "questions were impossible to decipher." Some women noted that the tests, prepared by some teachers to whom English was a second language, were particularly confusing. However, the women generally agreed that the examinations did not indicate accurately what they knew. Also they found that routinely they were unable to complete the examinations and could remember midterm examinations that "no one was able to finish."

The average grade on many examinations was approximately 30%. One woman recalls an often repeated experience:

> I was able to answer correctly only 30% of some of the tests for which I received an A grade. I believe that many people, who took a test and found that they could answer only 30% of the questions correctly, would just 'bag it'. They'd just become so intimidated, discouraged and depressed that they might not even bother to find out the results. They might not even finish the course. We were always shocked to find that 30% represented an A. This practice, I believe, was to scare people. It was a real intimidation tactic.

Another woman spoke for many when she said:

> I would get so afraid. I took every single test as though it was an IQ test. I felt that if I did poorly on the test that meant I was stupid. My self-confidence was not that high so that I really felt for the first two years that making it through this department was proof of my intellectual ability and if I didn't make it then I was stupid. That was the

> underlying theme of my whole existence. A lot of this undergraduate program is being able 'to take it.' Finally I started realizing that it was all a psychological trip, much of it I had put on myself. I cried a lot.

"The competition for acceptable grades was fierce." The women termed it "cut-throat." Almost all of the women associated this phenomenon with male orientation and called the grading environment "competitive, hierarchical, and militaristic." They observed that people in these surroundings were "kind of nasty and not giving help to each other, but rather keeping secrets to themselves."

Most participants felt that this area of their learning experience was one of the most frustrating. One woman spoke for many of us when she said:

> I would feel so broken down and then in the end I would get a grade that was fine. I would say to myself, 'If I had known that I was doing OK, I never would have put myself through all of this emotional garbage.' If somebody had just let me know that these feelings of insecurity and inadequacy I was experiencing were what everybody else was feeling, just let me know that I was an OK person, that I was an OK student, that I wasn't completely an idiot . . .

Student-Teacher Interactions Outside the Classroom

Since the lectures and assignments "often were confusing, incomplete or incorrect" and the classroom environment perceived as "hostile" and "chilly," the women needed other ways to find answers to their questions. The Department organized discussion groups for each of the beginning classes. Graduate teaching assistants lead these groups of 20 to 30 students. Women expected this environment to be less intimidating than the classrooms'. Some of them found that to be true, but others only found additional confusion. Many of the graduate teaching assistants spoke minimal English with strong foreign accents--profitable communication with them was nearly impossible. One woman said, "When I came to the discussion group hoping to get help or some clarification, my problems became worse." At times teaching assistants appeared to be giving instructions that conflicted with the instructors'. When this occurred, students' resulting work was marked wrong. When a woman questioned an instructor about this incongruence, he said, "I am the final word. You should have asked in my office." To see a teacher during office hours was another matter, however.

Instructors scheduled their office hours 1 to 3 hours per week per class. Considering that the average number of students in required classes at the 200 and 300 levels was between 50 to 100, it was difficult to access a teacher during these hours. Often students waited in the hallways for long periods of time, waiting for their turn to talk to a teacher and ask their questions. One woman spoke for many of us when she said, "I resented having to wait in a line, my time was precious too." Another woman recalled the words an instructor said at the beginning of the term, "My office hours are such and such; however, I have a reputation for not keeping them and I know you will write that on my evaluation at the end of the term." Some of the women never went to teachers' offices because they "could not get near any of them during office hours." Others had teachers who had "an open door policy" and found those teachers to be "understanding, encouraging, and helpful."

The women who were able to see teachers during office hours often found them to be "distant," "unreachable," "discouraging," and "unhelpful." For example, a female professor was reported to have explained her philosophy of teaching to a woman during an office visit in the following terms: "We only want to deal with the cream and if you don't feel that is where you are then get out. You shouldn't be here." Another woman, visiting a professor to ask for help on a mathematical concept (not a prerequisite to the course, but a requirement to answer the computer science homework), was told that she needed more help than could be given and she couldn't possibly learn the idea. Another woman seeking a clarification on an assignment from a male professor was told, "What do you want--the big hint?" Understandably, most of the women hesitated visiting professors in their offices because, as one stated, "I came out feeling so darn stupid--as though I had just asked the dumbest question in the world."

Some of the office visits with male professors proved threatening to the women. One woman recalled in the following terms an office visit to a particular instructor: "You had to put up with his ego, ('pretty female in my office, let's talk about other things'), in order to get answers to your questions."

Peer Interactions

The women interviewed described their need of support and the difficulty to find encouragement and support in the computer science environment. They commented upon the hierarchical ordering among people. One's position in the hierarchy, one of them said, seemed "dependent upon the amount and kinds of information that one possessed." Interactions among students appeared to be dictated by their relative positions in this hierarchy. Generally the women found themselves somewhat unwelcome into the hierarchical ordering. They were minority members of this environment right from the start.

Their numbers gradually decreased as they progressed through each class in the series of required courses. One woman voiced this common observation thus:

> I would be in classes all day and sometimes I could count the number of people in the room--there would be one or two females in thirty students. I remember especially as I got into the upper-division classes that it was very noticeable to me. It was very much on my mind. I don't know quite how it affects you but it does, it really does affect you. It affected me. There is something about that message, that physical fact, that raises the question, why aren't more women here? I am unusual in being here. As a woman, I am unusual. I am not like everyone else in the room in a major way. You really stand out as a female. You ask

> yourself, what am I doing here? Why aren't there other women here?

There was no explanation offered for what the women observed. They needed each other. "The women always seemed to know each other. We stuck together." Sometimes, however, there was no staying together. In some cases, women were decimated one after another by the rigors of the program. One woman described her involvement in a group of five or six women in this way: "We began studying together during the end of our first year (200 level). All of the others left by the end of the 300-level sequence." Speaking of conditions during a 400-level course, the lone survivor added, "This year was the hardest for me because I didn't have any of the friends I had had before."

The women found support where they could. A woman talked of a supportive relationship with another female student and believed that it provided her with the means "to survive in that program." With so few women in the program, she felt it was "important to have communication with other women, someone else who was in a situation similar to yours and with whom you could share a similar experience." "I think that is really important," she added. Three women interviewed met the need for support by forming study relationships with men and they found these men "extremely supportive." They, too, believed that their relationship was vital to their success.

Women more often were drawn to form relationships, even if casual ones, with other women because they needed access to information. They had discovered that, if they could not attend a class, most of the men in the class would not share with them the information they had missed. However, women in the same class willingly shared their notes with them. Besides, it was easier to establish rapport with women than with male students. As one woman put it, "I was not able to make friends with one male in a computer class."

The women identified several male-type students in the computer science classes. They seemed stratified in a hierarchical arrangement established according to how much knowledge of the machines they had. "Hackers," they felt, were at the top of the hierarchy. Who were these hackers? They were the "in crowd" in the computer science department. They were the "machine-oriented rather than people-oriented" men who were most visible during the night, who spent inordinate amounts of time playing either war or discovery games on the computers, who took over the building housing the department and conducted guerilla warfare with water-generated semiautomatic rifles, but could build "unreadable programs that excelled in efficiency and opacity." None of the women could think of one woman who fit this description. More importantly perhaps was the women's perception that hackers constituted the extreme personification of "a computer science person."

Hackers were reported to have a good, albeit negative, quality--rarely they actively discouraged women's participation in computer science. Another group of men, however, the loud, controlling, older, re-entry men were far more aggressive in expressing disapproval of women's presence in the program. Women talked of some of these male students as self-admitted sexists: "They told jokes with sexual innuendos" that made some women uncomfortable; they made wisecracks, "What are these women doing here? Shouldn't they be in home ec?" Sometimes they directly questioned the wisdom of their female colleagues, "What are you as a woman going to do with this?" Women, of course, found it difficult to work with them in groups. These men seemed to "feel really threatened by women." They actively encouraged women to leave the department. One of them suggested to one woman late at night in one of the computer laboratories that perhaps she was more suited for community college than for the University. His suggestion was made in response to a question she asked him regarding the mod function.[1]

"The image in my mind," recalled one women, "is of men working on computers. I can't even see a woman in my mind's eye in there. In the lab there are more men. There are just more men. The only women I have seen in this building that work here are the secretaries in the office, Sharon, and you."

Women's Experiences Derived From Enrollment and Achievement Data

Female undergraduate computer science students' experiences that emerged from the enrollment and achievement data were as follows: (a) On average female students comprised 25.5% of the total enrollments for seven years; (b) they comprised 30.64% of the beginning class for majors (CIS 201) and their numbers steadily decreased until they comprised only 23.22% of the students in the last required class (CIS 423); (c) in CIS 201, 52.34% of the female students received satisfactory grades--A's or B's--as compared with 47.24% of the male students; (d) in every required course except one, CIS 314 (only male instructors taught this course), a larger percentage of female students (67.4%) received satisfactory grades than did their male counterparts (65.17%); and (e) in every 300-level required course less than 13% of the female students were taught by a female professor.

The course in which women received proportionately fewer satisfactory grades was CIS 314, Computer Organization. Its content concentrated on the hardware of computer systems. Two of the women interviewed had decided to change their major from computer science while taking this course. They felt, as I did, that the course was poorly taught--its concepts generally were presented in a confusing and abstract manner.

From the data available I was not able to determine the number of women who withdrew from individual courses before the deadline for having a W recorded. However, the withdrawal pattern across courses was clearly distinguishable. Over the seven year period, the record shows that the ratio women:men changed from 1:3.26 to 1:4.31. Women's larger rate of withdrawal was not due necessarily to failing grades. In proportion, the record discloses that, during the 200- and 300-level required courses, men received failing grades three times more often than women.

Undergraduate female computer science majors, though few and taught overwhelmingly by men in courses overpoweringly filled with men, were shown to have a better success rate in the required courses than their male counterparts. Still, they left the program in larger numbers than their less successful male classmates.

Summary

Women's experiences, while studying computer science at the University, revealed an uphill educational journey fraught with obstacles and pitfalls on a winding road with arbitrary curves and precipices where crashing was an ever-present possibility. Although the recounting of these experiences was prejudiced by my own experience and by my interpretation of the other women's experiences, the path of computer science at the University between 1980-1987 proved difficult and challenging to the experienced student and often fatal to the inexperienced, most of whom were women.

In sharing our experience we all desired that we might be able to clear the pathway for other women. We talked about our discouragements and disappointments because we hoped that the illuminating of our problems might lead to the devising of programs where the difficulties we found would be eliminated and where the survival strategies we adopted would be incorporated so that women might be encouraged rather than hindered in their learning of computer science.

And they well may be encouraged. As our enrollment and achievement data clearly demonstrated, women are not less capable than the men who enter and continue in computer science. Women's underrepresentation in this program most likely stems from reasons other than intellectual aptitude.

Notes

[1]This function returns the remainder when performing division.

CHAPTER V

DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

Discussion

The focus of the present study was to analyze women's experiences while studying computer science in order to uncover what they perceived as barriers to their success and continuance in this field of academics. The study was based on my experience and on interviews with 22 women. These women were, or had been, enrolled in undergraduate computer science at a research-based public university in the northwestern United States during 1980-1987. It also was founded on the analysis of enrollment and achievement data from all required computer science courses during the same period.

The interviews elicited hundreds of transcribed pages rich in information about facets of the computing environment that resulted in more or less difficult barriers to many of these women. A discussion of these barriers, with supporting evidence from the literature, comprises the first section of this chapter.

The second section covers the recommendations that surfaced from the analysis of the interviews, my experience, and the review of the literature. Many of the women interviewed offered suggestions for enhancing the computer science environment that would attract and retain female undergraduate computer science students. My experience as an undergraduate and graduate student and as an assistant professor of computer science permeates these suggestions. Virtually no model program descriptions or intervention studies in computer science are available in the literature. However, relevant recommendations from studies done in related fields--mathematics, engineering, and science--are incorporated.

No doubt my own experience has influenced my perception of the barriers. I may have omitted some meaningful ones. Alternately, some barriers that I have considered important might appear inconsequential to other female participants. My goal was to describe as many barriers as possible. I believe that the illumination of seemingly superfluous impediments, however minor they may appear to some, is preferable to leaving them buried. An apparently minor barrier--a bad performance in a midterm exam--loomed sufficiently large to keep some women from continuing in the program.

The core variable that emerged from the Grounded Theory procedures outlined in Chapter III was: "barriers to women's success and continuance in computer science." These barriers fell into two major categories: (a) the barriers resulting from the overrepresentation of men; (b) the barriers emerging from the direct interaction of the women with the computer science environment at the University.

When I first began the present research effort my bias was that female computer science students emerged from high school less prepared than male students, that they generally did not receive satisfactory grades--A's or B's--, and, as a result, were forced to withdraw from the program. Therefore, I was interested in determining the course(s) in which this might have taken place. Thus, I analyzed all the grades for students enrolling in each of the required courses in order to determine the proportion of female students receiving satisfactory grades. In most cases, the results of this analyses challenged my bias--the majority of women had received satisfactory grades, and in all but one course, had higher achievement than men.

Many researchers have attempted to explain women's underrepresentation in the sciences by cognitive differences between the sexes. Generally, their studies have remained inconclusive. The analysis of the enrollment and achievement data used in the present study, revealed no cognitive deficiencies in the female undergraduate computer science students enrolled at the University between 1980 and 1987. In relation to their male counterparts who, more often than they, persisted in the program, women were more likely to get A's in the beginning course (CIS 201). In fact, in five of the eight required courses women received proportionately more A's. They also received a higher proportion of satisfactory grades than did the men in seven of the eight required courses. While it may be true that differential course participation influences the career choices women make, these data clearly indicated that the women who had made computer science their career choice were at least as qualified as any other student in the program.

Despite their superior cognitive performance, carried on through the seven years of the study, more women than men left the program. Women comprised 30.64% of all the students in the beginning course and only 23.22% in the last required course. The picture that emerged from this study was surprising and somewhat paradoxical: Generally women did better in computer science courses but dropped out of the computer science program much more often than men. The conclusion appears inescapable--factors, other than cognitive, work to eliminate female students from the study of computer science.

Barriers

Barriers Resulting from Overrepresentation of Men

Immediately upon entering the undergraduate computer science program, women were identified as different. Most of the people in classes, laboratories, and discussion sections were men. Women appeared out of place. This situation proved to be discouraging, frustrating, and isolating to many women. They faced what Josefowitz (1983) has called the "clonal" barrier--the fact that people in positions of authority are more likely to image as successful persons who are like them. As one of the women I interviewed said, "Because I was a woman there was definitely a sense coming from the teacher and the other people I was working with that I could never be as good as the males. It was just not going to be in my grasp to do this."

Because of their difference from the "norm," the women were at once more visible as women and less visible as students (Widnall, 1988). One woman summarized, "You really stand out as a female. You ask yourself questions: What am I doing here? Why aren't other women here?" As Ware, Steckler, and Leserman (1985) have found, this sense of difference may put an additional burden on women. One woman said, "I feel extra self-conscious because I am a woman. I really think there is an extra level of not wanting to appear stupid because you don't want people to associate women with being dumber." Ehrhart and Sandler (1987) described this barrier as follows:

> When their numbers are small, women may be overly visible within their departments and may, as a result, be subject to greater scrutiny. Consequently women may feel increased pressure to succeed, less confident of their abilities, less willing to take risks, and less able to negotiate for their needs. (p. 7)

Their increased visibility as women also can result in "social overattention" from male peers, which, in turn, can "lead to general wariness toward male students and reluctance to join in conversations or ask for help" (Ehrhart & Sandler, 1987, p. 7). The isolation resulting from this behavior may reduce women's chances of continuance in the scientific program of their choice (Widnall, 1988). As Ehrhart and Sandler (1987) have shown, "positive interaction with male peers helps women students in traditionally male fields to feel accepted as intellectual equals and colleagues" (p. 7).

"When you become a senior the faculty take notice of your existence for the first time." This observation, made by one of the interviewees, typifies what one may call the invisibility of women as students of computer science. Generally, women remained unnoticeable to male peers and teachers alike who, apparently, could not see the scientist hidden behind the female physical form (Widnall, 1988). More often than not, they expressed their blindness in ways that resulted in hindrances to the women. Women reported having to field unwanted social attention from teachers in order to gain access to academic information. Others recalled being actively discouraged by their teachers to continue their computer science studies. While admitting to her lack of self-confidence, one woman received the suggestion that perhaps she was "in the wrong field." "I'm tired of dealing with frustrated housewives," was a remark addressed to a re-entry woman who had asked for help.

Generally, teachers lectured as though the women were not present. The women reported there was no doubt in their minds that teachers spoke as if they were talking to a male audience. A teacher announced an examination with the words, "It's time to distinguish the men from the boys." The women present wondered where they fit. Teachers referred to computer professionals only as males. None of the women interviewed could remember even one occasion when a teacher had made mention of a female computer scientist.

Teachers also used the so-called "generic" words in their lectures. Although this usage continues to be debated in our society, there is abundant evidence that "he," "him," "his," "man," "mankind," etc. do not elicit gender neutral images in listeners' minds (Briere & Lanktree, 1983; Cole, Hill, & Dayley, 1983; Dayhoff, 1983; Hoch & Kushner, 1981; Korsmeyer, 1981; MacKay, 1983; Martyna, 1978, 1980a, 1980b; Miller & Swift, 1976, 1988; Spender, 1980; Thorne, Kramarae, & Henley, 1983; Wise & Rafferty, 1982). People envision male figures in response to these words.

The use of "generic" words erects a barrier for women, more powerful because of its subtlety. This barrier was present in most of the lectures they listened to and in most of the reading materials they had to read, thus contributing to the women's difficulty in envisioning themselves as computer professionals. Referring to this phenomenon, one woman confessed, "I never see a woman in my mind's eye." The use of generic words also has been shown to be related to the maintenance of sex-biased perceptions (Briere & Lanktree, 1983). We picture a data entry clerk as a woman and a computer scientist as a man. MacKay (1980a) has calculated that over a lifetime an educated American will hear "he" as a generic word more than one million times. This author has argued that the use of generic words may have serious social and psychological consequences. Likely it influences attitudes related to "achievement motivation, perseverance, and level of aspiration." MacKay wrote: It may "contribute to the feelings of importance, power, and superiority which are common among men, and the feelings of unimportance, powerlessness, and inferiority which are common among women" (pp. 47, 48).

All of this worked to keep women outside the circle of informal professional relationships with their peers and teachers (Widnall, 1988). Research has singled out solid partnerships formed early in the program as a major factor in continuance (Kersteen et al., 1988). The women felt the need for professional relationships but seemed incapable of penetrating the barriers raised by their male colleagues. They reported having difficulty accessing the charmed circle of camaraderie where men lived. A woman commented on the informal relationships between teachers and students. She said, "There is a lot more comradeship between male students and male teachers than there is with women." The women also reported difficulty interacting with teachers. When they were able to converse with them in their offices they often left feeling "stupid."

A woman, who tried to get through this barrier, described male students' reactions to her attempts to speak with them on a one-to-one basis. She said they behaved as though she was trying to pry something out of them. "I have never met so much opposition," she commented. Another woman said, "They don't really talk to me when it comes to computers--I'm just a woman." Male students also excluded women from informal study groups. When one woman asked to join one of these groups, she was asked, "Are you kidding?" Recently, the report, Looking for More Than a Few Good Women in Traditionally Male Fields, published by the Project on The Status and Education of Women, Association of American Colleges (Ehrhart & Sandler, 1987), described this barrier and added that "male peers tend to disparage women's abilities" (p. 9). Other research has concurred with this view (Deaux, 1984, 1985; Griffiths, 1985; Reskin, 1978). In fact, this barrier was the most often identified barrier in a survey of female undergraduate engineering students (Campbell & Staffin Metz, 1986).

In brief, women were not taken seriously as students of computer science by the men who surrounded them. Other studies have confirmed this finding (Griffiths, 1988; Widnall, 1988). In fields perceived as male, women had to prove themselves time and again (Kahle, 1985).

Most female students were denied female role models and mentors because there were few women on the computer science faculty at the University. This lack may cause women to consider themselves "deviant" in their career choice (Lawrenz & Welch, 1983). However, female faculty presence did not necessarily guarantee a benefit for the female students. The only tenure track female professor in the department at the University was discussed by several of the women. They believed that she "set the standards higher" for women and that "unless you really measured up to her standards you might as well . . ." She appeared to them as a barrier rather than as a facilitator of their experience. Ehrhart and Sandler (1987) have suggested that "some women who have managed to succeed in traditionally male fields against quite substantial odds may be less than sympathetic to other women's concerns" (p. 6).

The general opinion of all women participating in the interviews was that the computer science courses at the University were poorly taught. The instruction was often confusing, ambiguous, and unhelpful. Tobias (1986) reported that this was a major deterrent to the participation of able, but yet uncommitted, women in the mathematical and scientific fields. Moreover, this barrier--substandard teaching--"may be more problematic for women than for men" (Ehrhart & Sandler, 1987, p. 6).

The inability to access information was perceived as a barrier by many of the women interviewed. Much of this inaccessible information could have been found in answers to questions asked in class and during office visits. However, women generally kept quiet in and out of class, unable or afraid to formulate or ask questions. Ehrhart and Sandler (1987) wrote:

> Because men more frequently have access to information about what is going on, both in the institution and in the field, and because men talk more to each other, often sharing information and advice, women are at a distinct disadvantage. This 'old-boys' network' may be more firmly entrenched in fields where women have been relatively absent and result in women's status as 'outsiders' being considered the norm. (p. 7)

The demands of a computer science major were suggested by Campbell and McCabe (1984) as a factor in causing women's withdrawal from this field of study. All of the women I interviewed believed that the computer science major was extremely demanding of their time and location. They commented on the all-consuming effort necessary to prepare assignments and read the textbooks. One woman described this barrier well: "You must be a unidirectional person. You can have nothing else in your life. You must be willing to sacrifice a lot."

The stress produced by unrealistic demands and exacerbated by the "fierce competition" for satisfactory grades resulted in conditions of secrecy and isolation among the students, caused them to withhold help from each other, and created a "cut-throat" environment. A survey of 427 women entering undergraduate engineering singled out the "highly competitive" nature of the engineering program as the "biggest" barrier to women entering that field (Campbell & Staffin Metz, 1986).

As seen above, the women interviewed were kept outside the male network of acquiring and relaying information. Moreover, fewer women than men had acquired computing experience during their years in high school--"casual user" often was the type of experience girls acquired in secondary school (Becker & Sterling, 1987; Chen, 1986; Fetler, 1985; Kiesler et al., 1983, 1985; Lockheed & Frakt, 1984; Miura & Hess, 1983; Wilder et al., 1985). Furthermore, prior experience with computers has been demonstrated to be the most consistent predictor of success and continuance in beginning undergraduate computer science courses (Campbell, 1983, 1984; Durndell et al., 1987; Evans & Simkin, 1989; Howerton, 1988; Konvalina et al., 1983; Martin, 1984; Nowaczyk, 1984; Oman, 1986; Taylor & Mounfield, 1989). Campbell (1984) and Campbell and McCabe (1984) have shown that these two factors--the inability to access information and the lack of prior experience with computers--formed a formidable barrier that prevented 60% to 70% of female undergraduate computer science students from continuing beyond the first year of study.

Moreover, Ehrhart and Sandler (1987) stated that in fields where women are underrepresented they may "develop extraordinarily high standards for themselves as a prerequisite for staying in the field, so that women with grades and competencies equal to those of their male peers may nevertheless be disappointed in themselves and end up dropping out or changing fields" (p. 7). Campbell and McCabe (1984) discovered a negative correlation between women's high school rank and their continuance in a computer science major. This phenomenon perhaps caused some of the brightest women in my program to drop out of computer science.

Barriers Resulting from Women's Direct Interaction with the Computer Environment

The barriers discussed to this point appear to result from the paucity of women in computer science. The male presence appears to permeate the environment creating obstacles to women. Increasing the proportion of women in this field probably would work to alleviate many of these barriers. The remainder of the discussion in this section focuses on the barriers more directly related to the computer science environment.

The concepts of power and control (Carberry, Cohen, & Khalil, 1986; Martins, 1989) play a "fundamental role" in and provide "the framework" for the formation of a computer program. These concepts reflect a masculine view of reality

(Bush, 1983; Eisenstein, 1983; Flax, 1983; Gilligan, 1982; Spender, 1985; Walby, 1986) and have been shown to be alienating to women (Belenky et al., 1986; Gilligan, 1982; Spender, 1985).

A perusal of any computer science textbook reveals that hierarchy is interwoven throughout the theories of computer science and the machines. File systems, such as the one contained in the UNIX operating system, are built in a hierarchical tree structure. Again, hierarchy represents a masculine view of reality not espoused by women (Gilligan, 1982; Keller, 1985).

The organizing themes of computer science--control, power, and hierarchy--may have emerged from its military background. The militaristic and violent themes are reflected, not only in its concepts, but also in its technical jargon (Bork, 1988; Shore, 1985). Students are taught to "code" in the beginning courses and utilize this skill throughout the program. One woman said when she first heard the word "code" she envisioned the "D.O.D."

Operating systems are resplendent with commands that reflect their military origin. Shore (1985) provided an excellent example of this facet of computerese--the technical jargon of computer science--when he described a systems programmer's response to one of his questions:

> Your last hack crashed the system. One of your processes branched to an illegal address, tried to execute Joe's code, and died after committing a fatal protection violation. The broken pipe killed seven

> more processes, hung two others in a deadly embrace, and eventually caused the system to bomb with a core dump. (p. 41)

Shore (1985) stated that the violent nature of computerese encourages anxious computer novices to the same degree that medical humor does a preoperative patient.

Lakoff (1983) wrote that technical jargon serves as a "secret handshake" used to identify those who do not belong to the group. Technical codes, she asserted, are "exaggerations of masculine distancing, or power-oriented style." She felt that the use of these codes declared: "I (the user) am more powerful and valuable than you (the nonuser)" (p. 41). This barrier was particularly powerful in denying women access to computer science for in seeking to gain information by asking questions they immediately were identified as outsiders.

Operating system commands originate with the developer of that system. These commands vary from machine to machine and system to system. Moreover, they usually are cryptic, nonmnemonic, and have little reference to previous knowledge. They are nearly impossible to deduce. In a study (Furnas, Landauer, Gomez, & Dumais, 1987) the deduction of unfamiliar commands produced failure rates of 80% to 90%. Although no studies have examined the psychological effects of the constant utilization of commands couched in masculine, violent, militaristic, male sexual, and, at times, misogynistic terms, it is plausible to believe that they had negative effects, particularly on female users.

The best way to access these codes was to ask a colleague. However, as we have seen, this method of gaining access to information proved quite difficult for the women. One of them described the barrier as follows:

> I am trying to learn an editor and the documentation is very poor. The way it works--you don't go to your co-worker who has used that editor and is an expert and say, "Can you spend 10 minutes getting me started on this?" That is not how it is. People learn it for themselves and it takes 3 hours. That is the standard. Do it on your own. Don't ask for support. No one gives each other support because we all have to make it on our own and figure it out on our own. I see it more as this male, competitive style.

The male students didn't seem to have this problem--they helped each other (Ehrhart & Sandler, 1987).

Another barrier mentioned by many of the women was the difficulty they had in gaining access to a computer in the computer laboratory. Ehrhart and Sandler (1987) reported that women at one school admitted that they were "at a disadvantage when competing for scarce computer time because the accepted way of gaining access to computer terminals is to be physically and verbally aggressive" (p. 6). I observed this myself. Men allowed their friends, men also, to have the computer terminal after they had completed their work, thus circumventing those waiting in line. Women felt incapable of using this same method of gaining access to a computer. Several of them sacrificed instead to purchase a computer so they could avoid the barriers set up in the computer laboratories.

Some laboratory assistants were hackers. These members of the computer environment have previously been discussed. They warrant mention here because they represented for the women at once the embodiment of the successful computer scientist and the least attractive of men. Unable to identify with the latter picture, the women saw themselves as lesser than they, as users, not knowers, of the computer (Turkle, 1988).

The barriers women faced in the computer science environment have been classified by researchers as elements of the Computer Culture (Dubrovsky et al., 1986; Griffiths, 1988; Kiesler et al., 1985; Sproull et al., 1984; Steele, Woods, Finkel, Crispin, Stallman, & Goodfellow, 1983; Turkle, 1984, 1988). Kiesler et al. (1985) defined the Computer Culture as a "social system consisting of shared values and norms, a special vocabulary and humor, status and prestige ordering and differentiation of members from nonmembers" (p. 453). All of these investigators related that women had difficulty interacting with this culture. Women found it alienating in the extreme.

Its goals and applications often are directed toward the creation, maintenance, and operation of war. As Faulkner and Arnold (1985) have remarked, these goals

> are not necessarily women's goals. The actual practice of technology is often alienating to women--demanding or at least encouraging traits which leave many women cold, and which offer little promise of a more socially

> aware practice. Women are excluded from technology (partly) because they find it alienating, and they are alienated from technology because they are excluded. The technology we meet today is both cause and result of women's oppression. (p. 6)

In summary, the following barriers working to alienate women from computer science were identified in the present study: (a) the "clonal" barrier: Male computer scientists image men--not women--as potentially successful, because they are like them; (b) the isolation of women caused by their being different from the "norm"; (c) the inability of male peers and teachers to see women as professionals like them; (d) the tendency of male peers and teachers to see women as sex objects; (e) the widespread use of "generic" words that universally, unambiguously, and uninterruptedly keep asserting male presence and superiority; (f) the male peers' and teachers' exclusionary practices that keep women outside of beneficial informal professional relationships; (g) male peers' and teachers' disparagement and underestimation of women's abilities; (h) the lack of female role models and mentors; (i) women's difficult access to essential informal prerequisites; (j) women's lack of vital prior computing experience; (k) poor teaching; (l) women's fear of asking questions; (m) women's difficulty to access essential technical information; (n) the time and location demands of the major; (o) the female-alienating environment of the operating procedures, values, and power structures of the Computer Science Department; (p) the highly competitive climate of the program; (q) the elimination policies of the department; (r) women's lack of support from faculty; (s) the inadequacy of evaluation instruments and procedures; (t) the alienating nature--content and presentation--of computer science textbooks; (u) the foundational computer science ideas and their reflection of male reality, values, ideas, and characteristics; (v) the militaristic, violent, male sexual, and misogynistic nature of computerese; (w) the cryptic, arbitrary, and nonmnemonic nature of operating system commands; (x) the lack of assistance in computer laboratories; (y) women's difficulty of access to a computer in the computer laboratories; (z) the alienating nature of the computer laboratory milieu; and (aa) the computers themselves.

Recommendations

The first recommendation for a computer science environment and program more congenial to female undergraduate students is, of course, to minimize the barriers described above. To deny the existence of these barriers is to maintain present conditions and accept their unfairness to a large segment of the college student population. To accept them and others I might have overlooked is to take a step in the direction of modifying the status quo. The initial requisite is minimal: It is to become aware of the existence of these barriers. Students, staff, and faculty of both sexes need to accept the responsibility to begin the process of change.

Practical Applications and Connections for Theoretical Concepts

Many of the women interviewed believed that their study would have been facilitated and strengthened if they had been able to apply theoretical concepts to other disciplines of interest to them. Several investigators have made similar suggestions (Belenky et al., 1986; Campbell & Staffin Metz, 1987; Didier, 1990; Fisher, 1984; Hawkins, 1985; Lustig-Selzer, 1988). For example, women could be assigned research projects (Leveson, 1989) or internships could be arranged (Blum & Givant, 1982) in their areas of interest. These would enrich the academic component of a program. After reviewing intervention programs, Stage, Kreinberg, Eccles, and Becker (1985) concluded that a strong academic emphasis is one of the features of a successful program.

In addition, providing a context for an abstract concept would allow students to fit these ideas into a larger framework (Belenky et al., 1986). Philpott (1988) reported success when using "superordinate training"--building a framework within which to hang a new theoretical idea.

Visual Models to Clarify Abstract Concepts

Many computer science theoretical concepts are verbally described. Most of these concepts are abstract and difficult to understand without visual models. Research has shown that students were able to grasp ideas more rapidly and accurately when visual representations of abstract theoretical concepts were used (Blum & Givant, 1982; Bradford, 1987; Cunniff, 1988). Hence, models of data structures, perhaps similar to molecular structures in organic chemistry, could be used to clarify aspects of computer science education that students have difficulty understanding when explained verbally.

All-Female Classes

Several researchers (Collis, 1985; Fox, 1974; Lustig-Selzer, 1988; MacDonald, 1980; Macfarlane & Crawford, 1985) reported on efforts to teach mathematics and/or science to all-female classes. They found that female students were positively affected by this strategy. Fifty-six percent of the women in a women-only mathematics class at Mills College went on to enroll in the next mathematics course. On the other hand, only seventeen percent of the women in a comparable coed class continued in their study of mathematics (MacDonald, 1980).

Computer Anxiety Combating Strategies

Tobias (1976, 1978) engendered hope to the mathematically anxious student by offering math anxiety courses. This idea presumably could be used productively with computer anxious students.

Pre-Major Classes

The review of the literature clearly indicated that some women choose a computer science major with little prior experience with computers. This lack could be filled by a pre-major class that would provide missing information and experience. Pre-major classes have been shown to assist students' retention and achievement in mathematics, computer science, and science programs (Campbell, 1984; Sells, 1978; Zoller, Ben-Chaim, & Danot, 1987).

Minimum Typing Speed

Students wait in line for computers, not only because of limited availability of machines, but also because many of the students type slowly. This represents a handicap that needlessly prolongs their work. A minimum typing speed should be strongly recommended to, perhaps even required of, entering computer science students.

All-Female or Gender-Balanced Work Groups

During the undergraduate program much of the homework is assigned, not to individual students, but to groups of students. Teachers need to monitor the composition of these groups. Groups in which a woman is the only female member have been shown to be detrimental to women (Webb, 1984a, 1984b, 1985; Wilkinson, Lindow, & Chiang, 1985; Wolman & Frank, 1975). Wolman and Frank (1975) reported in their study that all women in this position became deviants, isolates, or low status members in their work groups. The women in the present study pointed out that the all-female or gender-balanced work groups benefitted them most.

Cooperative Rather Than Competitive Environment

Women place higher value on cooperation than on competition (Belenky et al., 1986; Hawkins, 1985; Lockheed, 1985b; Lustig-Selzer, 1988; Spender, 1985; Turkle, 1984, 1988). The classroom and laboratory environments, the evaluation instruments and policies, and the operating procedures of the department should reflect more cooperative values. For example, the elimination of grade rationing would help reduce competition.

Support Systems

A support system must be constructed to relieve some of the pressure women feel while in this program. Cobb (1979) suggested that female scientists and graduate students should spend 48 hours with new majors to let them know "we're here." Also the computer science program could offer lectures and informal discussions given by female professionals thus equipping female students with realistic views of the career for which they are preparing and exposing them to role models and mentors. In addition, advisors and teachers "could correct skewed conceptions and misinformation as they appear, help their students to develop an accurate picture of their abilities, and so perhaps prevent them from being prematurely and unnecessarily discouraged" (Ware et al., 1985, p. 81). Blum and Givant (1982), Campbell and Staffin Metz (1987), Ehrhart and Sandler (1987), Leveson (1989), and Ware et al. (1985) reported that this strategy was encouraging to women studying in a mathematical or scientific field.

The organization of peer support groups should receive careful consideration. These groups have been shown to contribute to critical peer interactions that lead to more realistic appraisals of one's abilities and to the encouragement and support of women in this challenging and difficult field (Blum & Givant, 1982; Kersteen et al., 1988; Leveson, 1989; Ware et al., 1985).

Flexible Intervention Program

Moreover, Stage et al. (1985) suggested that in order for an intervention program to be successful it must employ multiple strategies. In other words, it must be a dynamic program that changes and adjusts to the needs and interests of the women and men enrolled in it.

Caring, Supportive, and Competent Teachers

Finally, the program must be staffed with innovative, competent, caring, and supportive teachers. In the present study the women interviewed stressed the vital role teachers could play in the success and continuance of female undergraduate computer science students.

Conclusion

The question, "Why do so few women study undergraduate computer science?" requires an answer. The implementation of the recommendations listed above most likely would result in minimizing the barriers uncovered in the present study. This, in turn, probably would result in the retention of larger numbers of women in undergraduate computer science. However, even then, the question would be answered only partially.

Yet, the question must be fully answered. Women must find their way into all levels of computer science.

The computer appears to be influencing, gradually more directly and profoundly, every aspect of our society. Presently, many of its uses lead to war, destruction of natural resources, and denial of personal freedom. Yet the computer has the potential to be a powerful remodelling instrument of a better society.

It is unlikely that the present militaristic use of the computer will change without the infusion of new thinking--women's--at the level of designing the machines and the systems that operate them, the creation of software, and basic research.

No substantial change in women's underrepresentation in computer science will occur until the women and men who become parents, teachers, counselors and advisors, educational administrators, writers of computer-related materials, computer scientists, software engineers, systems analysts, and computer engineers change their views of women.

All of the people connected with this field need to become aware that the major obstacle to women's success and continuance in computer science is the stereotypical view held by most of us that computer science is not a "proper" occupation for women.

To paraphrase Rothschild (1983), greater representation of women in computer science will bring a necessary balance to its scholarly inquiry. The feminist experiential and holistic approach could transform such inquiry and make it greater than the sum of separate female or male endeavors (p. 222).

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