Persistence in Computer Science

by

First-Year Students at the University of Victoria

by

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B.Sc., University of Alberta, 1971

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Abstract

The primary purpose of this study was to examine possible gender differences in persistence in introductory university-level computer science courses. This investigation was done using path analytical methods to test models for persistence based on earlier studies on gender differences in technical subjects: computer science, mathematics, and the physical sciences. The secondary purpose of the study was to suggest possible intervention strategies based on the path analysis which could possibly increase the persistence rate of all students, but especially female students in computer science.

The subjects for this study were all students enrolled in Computer Science 110, the introductory computer science course at the University of Victoria in September, 1986. Of the 308 students who responded to the survey questionnaire, only 269, 189 males and 80 females, who indicated their intention to persist in computer science were retained for testing the path models. The path analytical models being tested involved nine variables: attitude to mathematics; previous computer courses; previous computer experience; age; tendency to stereotype computing and computer users; comfort level, prediction of success, and achievement in Computer Science 110; and persistence measured by whether or not the student enrolled in the subsequent computer science course.

The models predicted that the persistence of female students would be affected more strongly by the affective variables--attitude to mathematics, tendency to stereotype, and comfort level--while the persistence of males would be more dependent on the "concrete" variables--previous computer courses, previous computer experience, and achievement in Computer Science 110. The data analysis revealed that the overall model for females accounted for 73% of the joint variance in the included variables for the female sample while the male model accounted for 63% of the joint variance on the included variables for the males sampled.

The results of the path analysis revealed that there is a gender difference in the factors which affect the persistence of students in computer science. Of the variables included in the models, achievement level in Computer Science 110 and previous computer experience related to persistence most positively for both male and female students although the relationship was more positve for males than females. The persistence of females was more positively related to the affective variables than was that of the males. Age and previous computer courses were negatively related to persistence for all students with the relationship being more negative for females.

The study seems to indicate that interventions at two levels, prior to university entrance and at the university level, should occur to improve the persistence rate of first-year computer science students. Interventions prior to university entrance could include increasing access to computers for all students in a variety of subject areas; reviewing the high school computer science curriculum; affecting a positive change in the attitude to mathematics of female students; and increasing the awareness of students, teachers and concerned others of factors related to persistence in computer science. At the university level interventions should focus on making the learning environment as supportive and comfortable as possible for students and as such more conducive to persistence in computer science.

The models tested in this study are by no means definitive models for persistence in computer science. The results of the study and literature review indicate the need for further study of models for persistence which include these factors as well as academic factors such as high school mathematics, science, and English grades; computer languages previously studied; and the type of computer--mainframe or micro--used in the introductory computer science course at the university.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

Acknowledgments

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Finally, but by no means least, thank-you to the College of New Caledonia for the opportunity to have this year of renewal and study.

Dedication

This study is dedicated to

my husband, Keith,

and sons, Brian and Robert,

who willingly changed their lives for a year

so that I could fulfil a dream.

CHAPTER 1

Introduction

In recent years there has been growing concern about the markedly different participation rates in computer science courses of male and female students at the college and university level. More male students enroll in computer science programs (Ware, Steckler, & Leserman, 1985), and males are also more likely to continue in and complete these programs than are female students (Campbell & McCabe, 1982). Hawkins (1985), Hess and Miura (1985), and Kahle (1985) have all expressed concern with this developing gender difference in computer science. This difference in participation has many possible similiarities to that already established in mathematics and the physical sciences.

The difference in participation rates of women in mathematics has been a concern since the early 1960's when the project TALENT Women and Mathematics study was designed to investigate gender differences (Wise, 1985). Awareness increased even more in 1973 when Sells (1980) wrote that only 8% of freshmen women at Berkeley in the Fall of 1972 had completed sufficient mathematics courses to qualify for freshman calculus while 57% of men had the required prerequisites. At the same time concern about the participation of women in the physical sciences was also developing (Behringer, 1985; Matyas, 1985a).

Recent statistics in both Canada and the U.S.A. show that the concerns in these areas are justified although the differences are not as great as they were in the early 1970's and before. In 1973 in the U.S.A. 51% of males and 32% of females writing the SAT had four years of mathematics; in 1981 54% of males and 43% of females had four years of mathematics (Chipman & Thomas, 1985). The numbers of women receiving doctorates in science and engineering in the U.S. has changed noticeably over the last 30 years (Behringer, 1985). In the physical sciences, 1950-59, 3.7% of doctoral degrees were awarded to women; 1960-69, 4.6%; 1970-79, 8.8%; 1980 13.9%. Engineering showed an even more significant change: 1950-59, 0.30% of doctoral degrees were awarded to women; 1960-69, 0.40%; 1970-79, 1.4%; 1980, 3.8%. During the same period doctoral degrees to women in social sciences went from 11% in 1950-59 to 52.9% in 1980 and in all fields from 6.7% in 1950-59 to 29.1% in 1980 (Behringer, 1985).

In Canada the number of female students seeking undergraduate science degrees has risen in the past ten years so that women now make up about 33% of students registered in science majors. However, many of these are registered in the biological sciences. In British Columbia women make up approximately 25% of undergraduate students in computer science, approximately 20% of mathematics students, but still make up less than 10% of students in physics and engineering. Figure 1 documents the participation of women in undergraduate programs at British Columbia universities (Palmer, 1983).

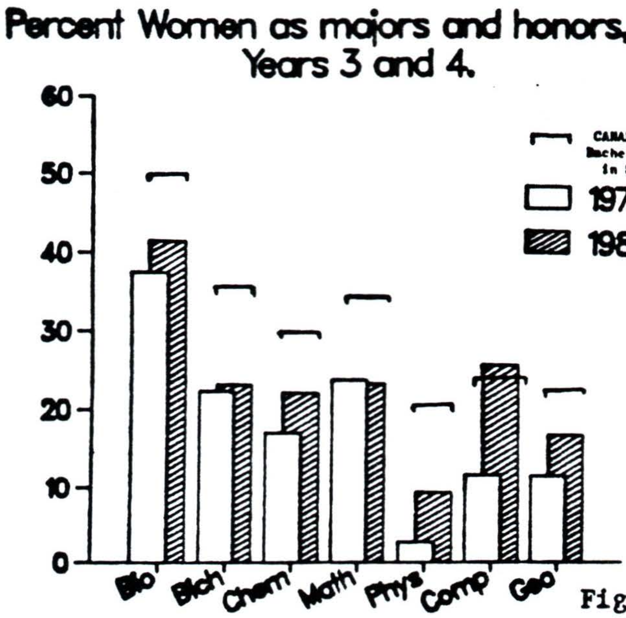
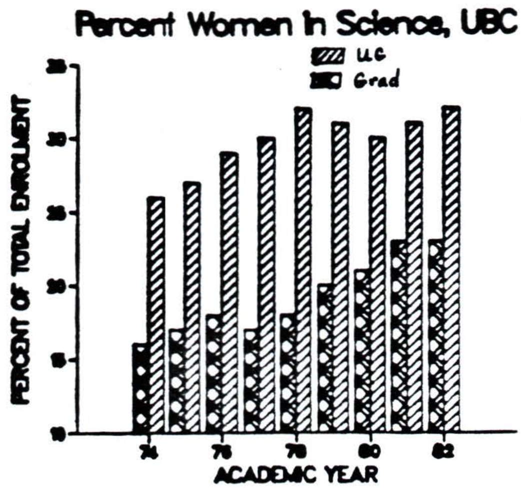


Fig. 6



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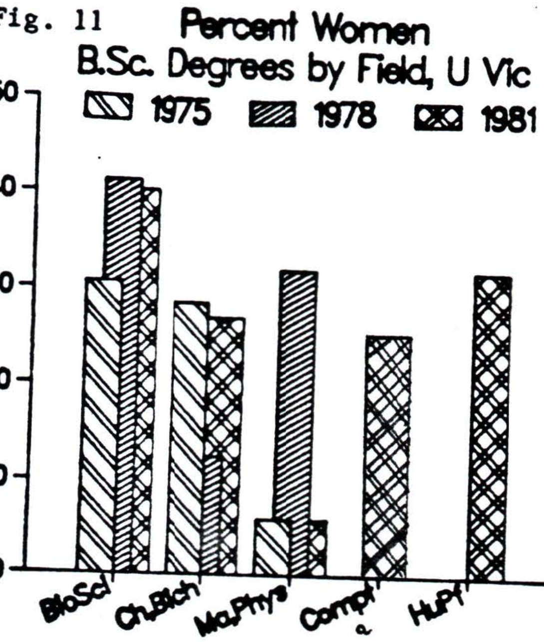


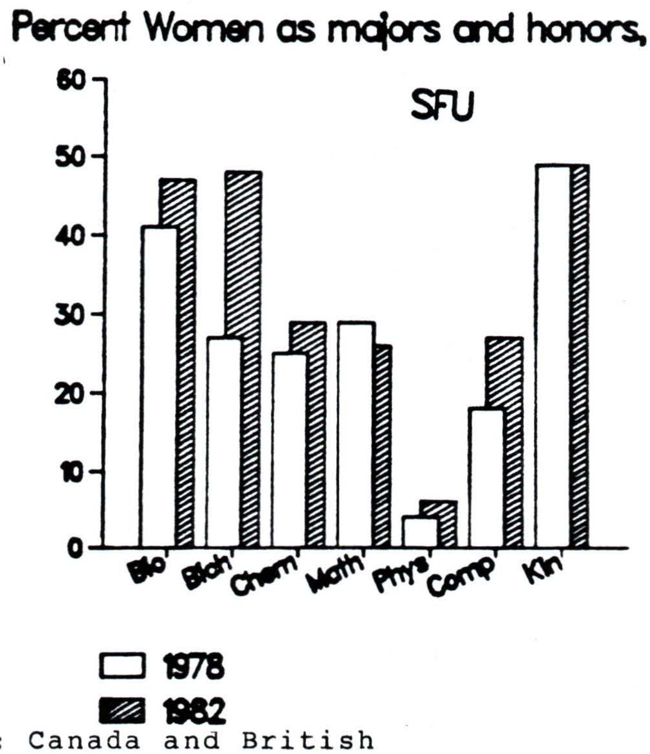


Figure 1

Note. From "Undergraduate women: Canada and British Columbia" by E. Palmer, 1983, Proceedings of the First National Conference for Women in Science, Engineering, and Technology, p. 100-102.

a: 1981 figures for computer science graduates were obtained from the Computer Science Department at University of Victoria. Figures for 1975 and 1978 computer science graduates are include in the Math/Physics numbers.

The number of women receiving masters degrees in Canada has changed from 22% in 1970 to 37% in 1980. A similar increase has been shown for PhD.'s (9% in 1970 to 23% in 1980)(Einstein, 1983). Much smaller changes have taken place in science. In 1970 13% of master degrees in science went to women (Einstein, 1983); in 1980 17% went to women (Mura, 1983). Increases in the enrolment of women with science majors in graduate schools are taking place. At UBC increases from 16% in 1975/76 to 23% in 1982/83 occurred. Figure 2 shows a comparison of Masters and PhD's awarded to women in Canada (Einstein, 1983).

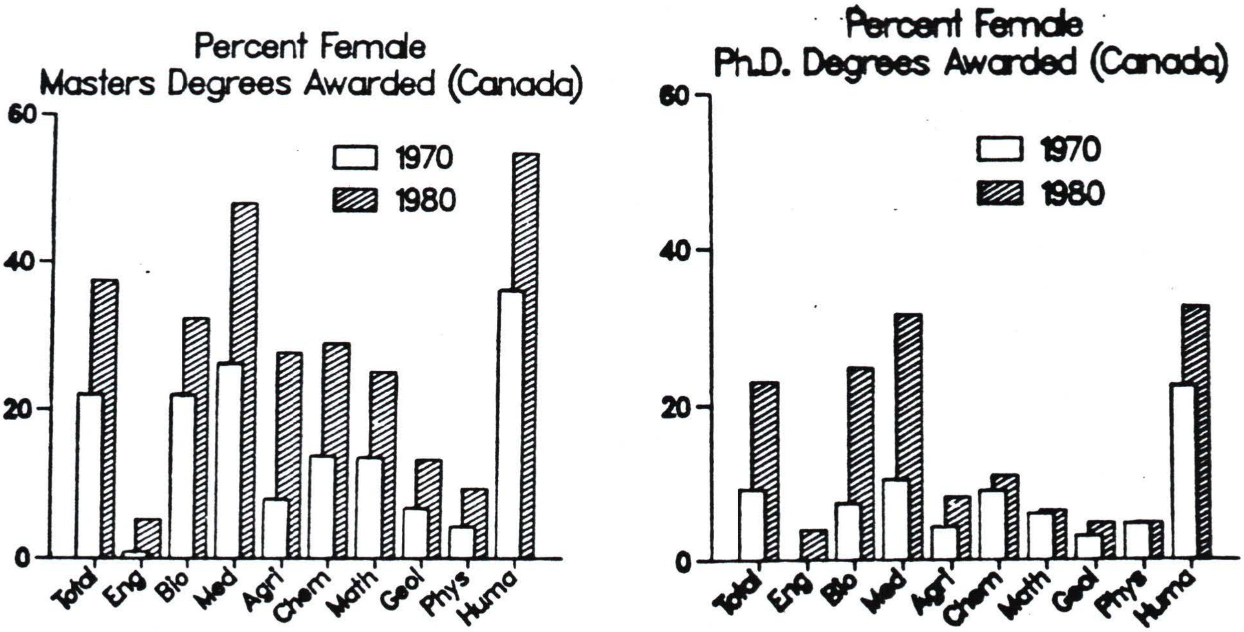


Figure 2
Note. From "University women: Graduate and faculty statistics" by J. Einstein, 1983, Proceedings of the First National Conference for Women in Science, Engineering, and Technology, p. 97-99.

Statistics on the work force of the U.S.A. in 1980 indicate that women make up 13% of physical scientists, 19% of its mathematicians, 22% of the computer scientists, 22% of life scientists and 2% of engineers (Ware, Steckler & Leserman, 1985). These figures are similar in Canada with significant improvements in the number of women in engineering in Canada in recent years (Ellis, 1983).

Despite these gradual increments, a considerable gender discrepancy in participation in mathematics, physical science, and computer science still does exist. Mathematics has long been discussed as the "critical filter" for girls with respect to science and engineering degrees (Sells, 1980). Mathematics, physics, and/or chemistry are prerequisites for postsecondary courses in the physical sciences, computing, and engineering. Girls often eliminate these fields as career options by not taking these courses in high school or not taking the required prerequisites for these courses. In Ontario high schools in 1979, 11% of females as compared to 31% of males enrolled in physics and 22% of females as compared to 32% of males enrolled in chemistry (Scott, 1983). In a 1979 study undertaken by M. Suderman for the Ottawa Board of Education 76% of girls in Grade 11 did not study any physics or chemistry (40% for males) and by Grade 12 26% of the girls studied no mathematics as compared to only 4% of boys (Pepin, 1983). Sixty-seven per cent of the Grade 12 boys in Suderman's 1979

Ottawa sample were enrolled in "advanced" or "enriched" mathematics while only 35% of the Grade 12 girls were enrolled in these classes (Menzies, 1982). The technical courses surveyed by Suderman in Ottawa showed a ratio of 6:1 participation of boys to girls (Menzies, 1982). The lower participation rates are not a measurement of ability as in both physics and chemistry in Grade 13 in Ontario a higher percentage of girls passed than did boys (Pepin, 1983). This lack of participation in math and science by female students is a handicap to further science, technological, business and professional training (BCTF, 1983).

At present the number of females enrolled at the University of Victoria exceeds the number of males. In 1986 56% of the undergraduate students are female and 44% of the undergraduate students are male. However, in May 1987 only 18% of students receiving undergraduate degrees in computer science were female. Over the past seven years an average of 21% of the students receiving Bachelor of Science degrees in computer science were female, 79% were male. The percentage of females graduating in computer science in this time period has ranged from 13% in 1985 to 32% in 1983. At the graduate level at the University of Victoria 49.7% of students are female and 50.3% are male. In computer science approximately 10% of graduate students are female.

The Department of Computer Science at the University of Victoria has expressed concern with why the participation rate of female students in computer science is so different from that of male students and also why the persistence rate of female students in the computer science program seems much lower than the persistence rate for men. This concern is reinforced when the University of Victoria data concerning female involvement in computer science is compared to the experience at other British Columbia universities with about 25% female students in their computer science programs and by the research of those like Campbell and McCabe who related persistence in computer science to academic factors at the high school level.

Campbell and McCabe (1982) relate that in their study of persistence in a computer science major at Purdue University, men were more likely to persist than females. Of the students who indicated computer science majors on entry to their university 61% of males but only 39% of females persisted in this major. They observed that persistence was related to SAT-Math scores, SAT-Verbal scores, ranking in their high school graduating class, high school grades in mathematics, science, and English, and number of high school mathematics and science courses completed. Campbell and McCabe also relate that there were no significant differences on these factors between students who changed to majors in engineering or other sciences and the students who persisted in computer science majors. However, there were significant differences between these two groups and those students who changed to non-science majors or who withdrew from the university. Oman (1986) also notes that much of the variance in the introductory computer courses can be accounted for by mathematics proficiency; Peterson and Howe (1979) relate that success in high school mathematics and science courses correlates positively with success in introductory university-level computer science.

Of those students who persisted in computer science, males had higher SAT-Math scores, had completed more semesters of high school science than the females who persisted, but the females ranked higher in their graduating classes, and had higher averages in high school mathematics and English than the males.

A university can control the number of high school mathematics and science courses that a student has completed by setting prerequisite courses and can control to some extent the student's achievement level by setting an achievement level requirement on prerequisite courses and prior GPAs. However, these factors deal with only part of a student's experience prior to entering the computer science courses, and they have no connection with factors intrinsic to the computer science program which may influence the persistence of students.

Other extrinsic factors which could be considered as influences on persistence include age, prior computer experience, and completion of high school computer science courses. Intrinsic factors which warrant consideration include self-confidence with regard to course achievement, perceptions about computer science, attitudes towards and atmosphere within the computer science environment, attitude towards mathematics, and achievement in introductory university computer courses. Campbell and McCabe (1982) relate that success in the first year of the computer science program is a good indicator of success in the major. In addition to the research of Campbell and McCabe, much research is now being done which pertains to gender differences in computer science as has already been done extensively in mathematics and the physical sciences in order to identify the types of factors, both educational and socio-cultural, which seem to relate to these gender differences.

In present day society, when the use of computers is permeating every facet of society and the ability to use computers is fast becoming an essential skill for employment, people, especially women, may become handicapped if they lack appropriate computer skills. Technical professions offer high salaries and much job satisfaction. By not persisting in computer science training many women are limiting their opportunities for exciting careers with both high renumeration and personal satisfaction. Thus, it is important to pursue studies which may determine some of the factors which influence the persistence of students in computer science, especially the persistence of female students in computer science since it seems that the persistence rate of women is lower than that of men. It may also be possible to increase the participation rate of females in computer science courses if more is understood about factors which influence their persistence, achievement, and feelings about computer science.

CHAPTER 2

Review of the Literature

Factors Affecting Participation of Females in Mathematics, Science, and Computing

Factors affecting females' achievement and interest in mathematics, science, and computing courses generally fall into three categories: educational factors, socio-cultural factors, and personal factors (Chipman & Wilson, 1985; Hawkins, 1985; Matyas, 1985a)

Educational Factors

There are a variety of educational factors which affect participation by females in mathematics and physical science courses, and there is some indication that these factors may also influence persistence in computer-related courses.

Attitudes. There is no apparent difference in the attitudes of male and female students towards mathematics and science in the primary grades; however, during intermediate and junior high school grades the attitudes of both male and female students to mathematics and science become more negative (Duncan & Haggerty, 1984). This decline in attitude is more significant for female students than for male students (Duncan & Haggerty, 1984; Simpson & Oliver, 1985). Simpson and Oliver (1985), for example, found that males possessed a significantly more positive attitude towards science than did females in all grades except the ninth grade. However, in the area in which Simpson and Oliver's study took place only advanced students took science in Grade 9; thus, girls who were high achievers in science held the same positive attitude as the male high achievers. In grades where all students took science the males had a more positive attitude towards science than did the females.

In her study in England, Smail (1983) noted that gender differences in attitude to technical subjects and participation in these courses began to develop as soon as students were given a choice of courses. In the early teens, "adoption of masculinity and femininity is crucially important to them, so they choose subjects they consider appropriate to their future adult role" (Smail, 1983). Smail also notes that gender-related polarization is not as great in single-sex schools as in coeducational schools. Bright adolescent girls were also found to do better in an all girls' environment than in a coed setting by Brody and Fox (1980), and Kreinberg (1976).

In a study of students in Grade 10 accelerated mathematics courses and Grade 12 advanced placement mathematics courses, Casserly and Rock (1985) relate that grades in previous mathematics courses were the factor in their study which had the greatest influence on the students' self-assessment of their mathematics ability. The women in the Advanced Placement courses tended to have realistic assessments of their mathematical ability. In her study of students enrolled in university-level mathematics courses at universities across Canada, Mura (1987) observed that larger percentages of both male and female students overestimated their grades than underestimated their grades; however, at all five universities surveyed the women were less likely to overestimate their grades and more women than men underestimated their grades. Mura's study did not indicate a significant gender difference in the confidence of students to obtain a bachelor's degree, but did show a significant gender difference in their confidence to acquire a PhD with males expressing higher confidence than the females.

While self-confidence is an important factor, it seems that interest is also a major factor in the persistence of students in the study of higher level maths and sciences. Thomas (1986) reports that students who are more interested in science and mathematics are more apt to study mathematics or science at the postsecondary level than students who are less interested. Likewise, a positive attitude towards mathematics was highly correlated with participation in more mathematics courses (Armstrong & Price, 1982). In addition, interest in science seems to relate to a positive attitude to science and mathematics. Kahle (1985) relates that the following factors correlate with interest in mathematics and science for females:

1. academic performance and achievement (also found by Benbow & Stanley, 1980)
2. science oriented hobbies in childhood
3. encouragement to major in mathematics and science by significant persons
4. childhood aspirations, early career expectations
5. standard test performance (also found by Thomas, 1986).

Thus, it would seem that these factors would be related to the attitudes which females hold towards science and mathematics. Kahle (1985) also notes increased interest developing through access to informal mathematics and science activities; therefore, an increase in interest level can be actively encouraged by teachers and parents.

In the area of computers Collis (1985) related that girls had consistently less positive attitudes towards computers than boys had in her study of Grade 8 and Grade 12 students. Females in this study were also less confident towards computers than were the males. In a cross-sectional study of students in K-12, Wilder, Mackie, and Cooper (1985) found that although attitudes to computers were positive at all levels, attitudes decreased over time with girls always significantly more negative than boys. In a study of freshmen college students, females with experience in programming were less comfortable using the computer than males with no experience (Wilder, Mackie,& Cooper, 1985).

In their study of female college students interested in science majors Ware, Steckler, and Leserman (1985) found that the women's reaction to their first college science courses were critical to maintaining their interest in science as a career. Likewise, Campbell and McCabe (1982) relate that success in the first year of a university-level computer science program correlates with success in the major.

Achievement. There are contrasting views on the achievement levels of females in mathematics. Some studies have shown boys to perform better on some mathematical activities (Benbow & Stanley, 1980); other studies show that there is no significant difference in achievement levels of male and female students when they have studied the same amount of mathematics (Armstrong, 1985; Fennema, 1980). Differences in achievement levels begin to develop in high school when boys tend to take more math courses (Armstrong, 1985). Boys show superior achievement levels in problem solving skills (Armstrong, 1985).

In 1974 Maccoby and Jacklin (cited in Connor & Serbin, 1985) reported gender differences in spatial visualization. However, varying results have been reported in subsequent studies (Armstrong, 1985; Connor & Serbin, 1985; Fennema, 1980). Connor and Serbin (1985) have concluded that males may use visual-spatial relations more extensively in solving problems than females, while females tend to use more verbal methods than do males.

Casserly and Rock (1985) observed that both males and females who were successful in accelerated mathematics courses tended to persist in mathematics study. They noted that, although there was a positive relationship between self-assessment of mathematics achievement and persistence for male students, this relationship did not seem to exist for female students. Of the factors studied by Casserly and Rock (1985) the major factors related to the persistence of female students in mathematics careers were math grades and the encouragement of counsellors and teachers other than the math teacher. They relate that being in advanced placement mathematics seemed to give male students the self-confidence to pursue any career to which they aspired while female students, although in advanced placement mathematics, were influenced by grades and seemed to feel that they needed to excel before they could pursue math-related careers.

In reviewing literature on gender differences in science, Steinkamp and Maehr (1984) were unable to explain observed differences in science achievement. Boys outperformed girls on science achievement tests with the smallest differences being in biology and the largest differences in physical science (Erickson, Erickson, & Haggerty, 1980).

Achievement in computer education is often linked by students to achievement in mathematics (Hawkins, 1985; Lipkin & McCormick, 1986; Lockheed, 1985; Winkle & Mathews, 1982). Boys outperform girls at all levels in programming skills; and in addition, the girls' achievement in programming is related to their interest in the programming task and the teacher's interest in computing (Hawkins, 1985). In many classrooms computers are presently used to challenge bright students, usually male, in mathematics (Lipkin & McCormick, 1986).

Achievement in first-year computer science at universities has been linked to achievement in high school mathematics courses (Campbell & McCabe, 1982; Oman, 1986; Peterson & Howe, 1979). However, Greer (1986) relates that in his study of first-year computer science students at the University of Saskatchewan there was no association between participation in high school-level computer science courses and achievement in the introductory computer science course at the university level.

<u>Classroom treatment</u>. Differential treatment of male and female students in the classroom has often been mentioned as a factor in participation and persistence in mathematics courses (Brophy, 1985; Fennema & Peterson, 1985; Stallings, 1985) and in science courses (Morse & Handley, 1985). Teachers interact significantly more times with, and give

more positive reinforcement to male students than to female students (Fennema & Peterson, 1985; Morse & Handley, 1985).

Helson (1980) related that female mathematicians possessed personality characteristics of independence, assertiveness, adaptiveness, and initiative. However, these characteristics are not generally fostered and enhanced by the treatment of female students in mathematics and science classrooms (Fennema & Peterson, 1985; Morse & Handley, 1985). Teachers often have different expectations of female students than they have of male students; in response, students seem to live up to these expectations in the classroom (Erickson, Erickson & Haggerty, 1980). Eccles and Blumenfeld (1985), for example, report a Sex by Teacher Expectancy interaction. "Higher teacher-expectancy" males and "lower teacher-expectancy females" received more attention. It seemed that teachers passively reinforce sex-typed academic and career decisions made by their students (Eccles & Blumenfeld, 1985).

Providing equitable classroom participation with computers is a growing concern. Aggressive young male students tend to dominate the use of school computers while girls have more limited access (Lipkin & McCormick, 1986; Schubert, 1986; Sheingold cited in Hawkins, 1985). In the higher grades girls also have more limited access than boys as school computers are often concentrated in the mathematics area (Hawkins, 1985) and fewer girls than boys take senior elective mathematics courses. Teachers who are not comfortable with computers often use interested and expert male students to demonstrate computer activities for them (Dubois & Schubert, 1986). These teachers typically are not aware of the bias with regard to computer expectations in their classrooms (Dubois & Schubert, 1986; Lipkin & McCormick, 1986).

This unequal sharing of equipment is also apparent in the science lab where male students will dominate the equipment and leave the females to sit back and watch the experiment being done (Smail, 1983). This pattern continues to occur unless equipment is assigned.

Classroom experiences. Female students report very different experiences than male students report with regard to scientific activities and interests both in and out of school (Matyas, 1985a; Smail, 1983). Figures 3 and 4 summarize these types of gender differences.

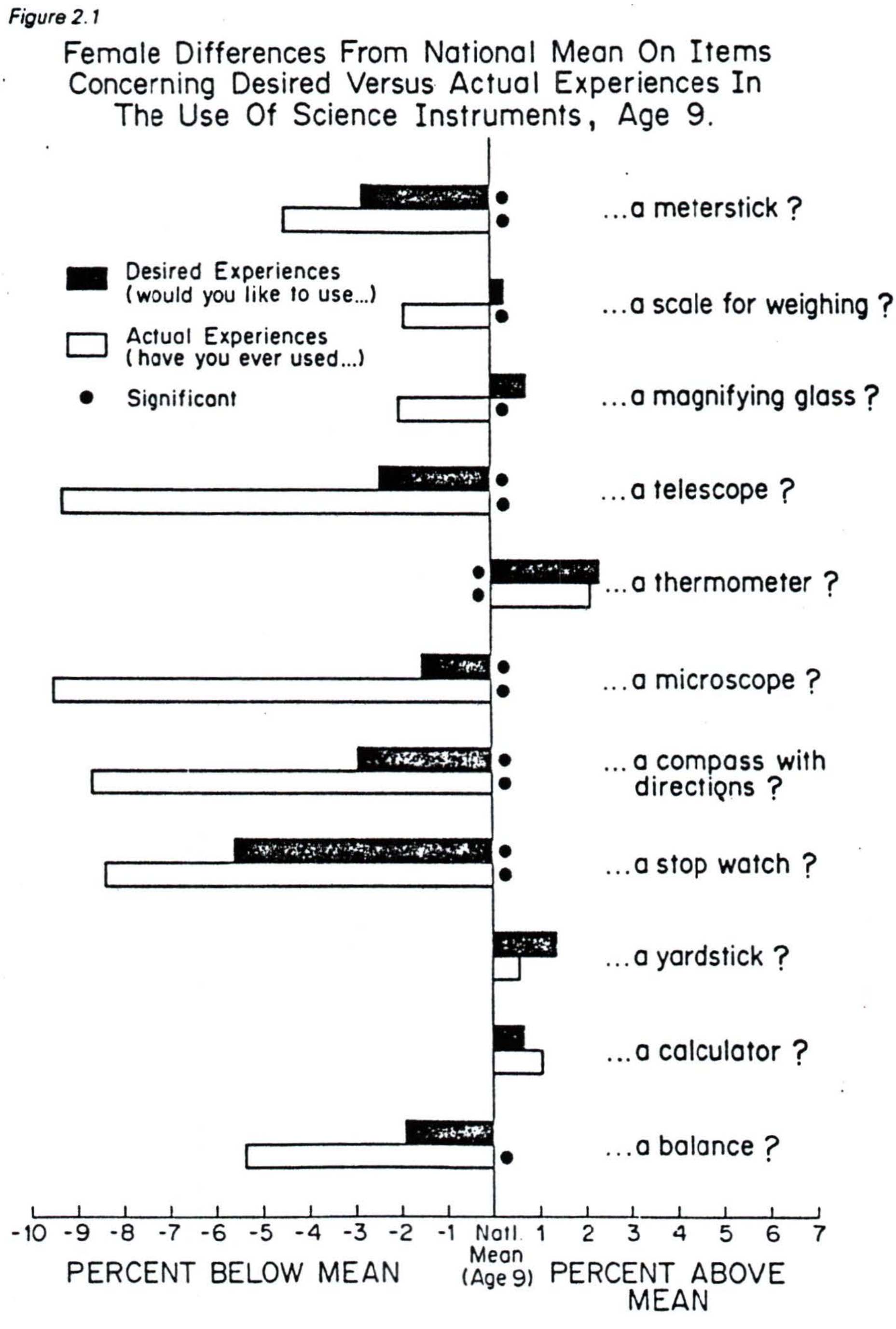


Figure 3

Note. From "Factors affecting female achievement and interest in science and in scientific careers" by M.L. Matyas, 1985, Women in Science, (p. 31), Philadelphia: Falmer Press.

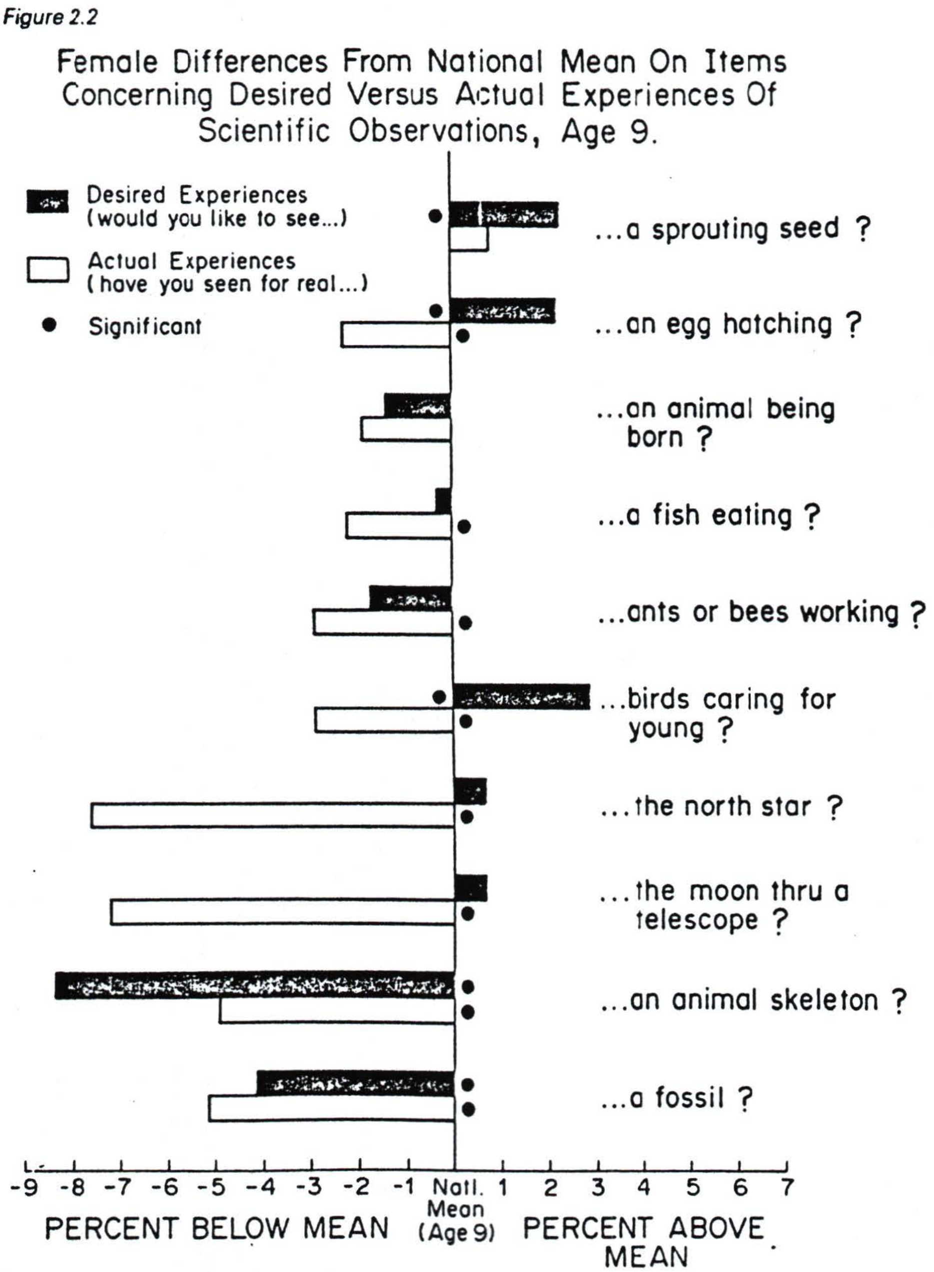


Figure 4
Note. From "Factors affecting female achievement and interest in science and in scientific careers" by M.L. Matyas, 1985, Women in Science, (p. 30), Philadelphia: Falmer Press.

The experiences which students have in the classroom are associated with how they rank their courses with respect to liking (Brush, 1985). Table 1 shows the results of a study in which students were asked to rank their degree of liking for the following subjects: biology, chemistry, English, history or social studies, languages, mathematics, and physics. While Table 1 indicates a decline in liking of mathematics and the physical sciences by both male and female students, Brush relates that female students indicate disliking these courses more intensely than do the males. The female students also see these courses as less useful and more difficult than do the males.

Table 1

Relative Rankings of Liking of School Subject

Grade					
Seventh	Eighth	Ninth	Tenth	Eleventh	Twelfth
Chemistry	Languages	Biology	English	English	English
Math	Biology	English	Biology	History	Biology
Languages	Math	History	History	Biology	History
Biology	English	Math	Math	Math	Math
English	Chemistry	Languages	Languages	Languages	Languages
History	History	Science	Chemistry	Chemistry	Science
Physics	Physics		Physics	Physics	

Note. "Science" was a combination of the ratings of chemistry and physics for ninth and twelfth graders.

From "Cognitive and affective determinants of course preferences and plans" by L.R. Brush, 1985, *Women and Mathematics: Balancing the Equation* (p. 137), New Jersey: Lawrence Erlbaum Associates, Extracurricular activities. Extracurricular activities and early childhood hobbies and career aspirations were also found to be significant factors in interest in mathematics and science (Thomas, 1986). This statement does not bode well for changes in the future when we consider the career and lifesyle aspirations of young girls in the recent study done for the Women's Bureau of Labour Canada (1986). Traditionally male occupations were the first choice of 93% of boys and only 43% of girls in this sample of Grade 1 to Grade 8 students from across Canada. Occupations in which more than 60% of workers are female, that is, traditionally female occupations, were chosen by 32% of the girls but only 1% of the boys. Males chose occupations related to computing and science as their first choice more frequently than females in all of the following categories: computer related occupations - males 19, females 11; scientists - males 14, females 3; engineers - males 6, females 3; astronauts - males 8, females 2; architects - males 11, females 3.

Thomas cites Kahle (1983), Fisher (1983), and Fox (1982) when she observes that for girls increased interest in mathematics and science is associated with access to informal mathematics and science activities. As girls seem to have little interest in extracurricular (non-required) science activities (Matyas, 1985a) (see Figures 5 and 6), the enhancement of their interest levels in these subjects does not seem likely to occur without intervention. In addition, girls show less interest in extracurricular computer activities such as computer camps and video games (Hess & Miura, 1985; Lockheed, 1986), and Sanders (1986) reports in her high school study that 40% of males report using the computer in their free time as compared to 8% of females.

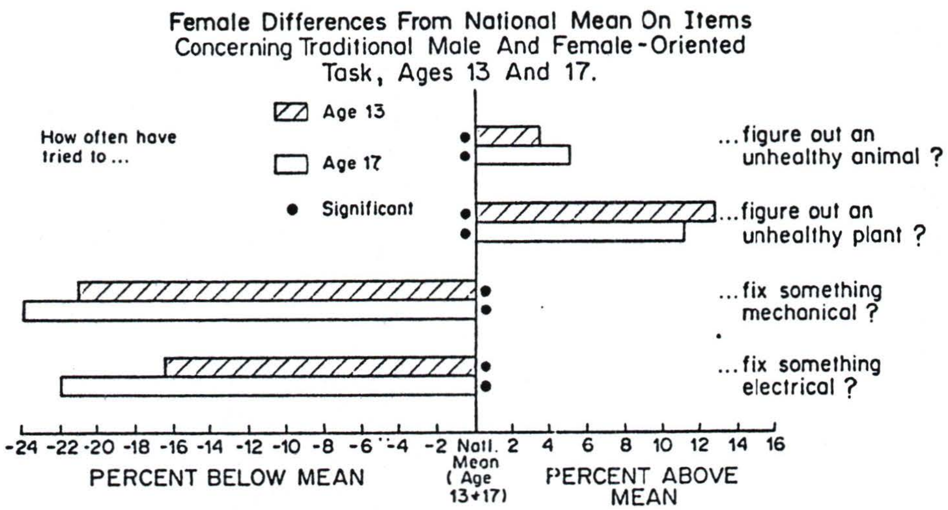


Figure 5
<u>Note</u>. From "Factors affecting female achievement and interest in science and in scientific careers" by M.L. Matyas, 1985, <u>Women in Science</u>, (p. 37), Philadelphia: Falmer Press.

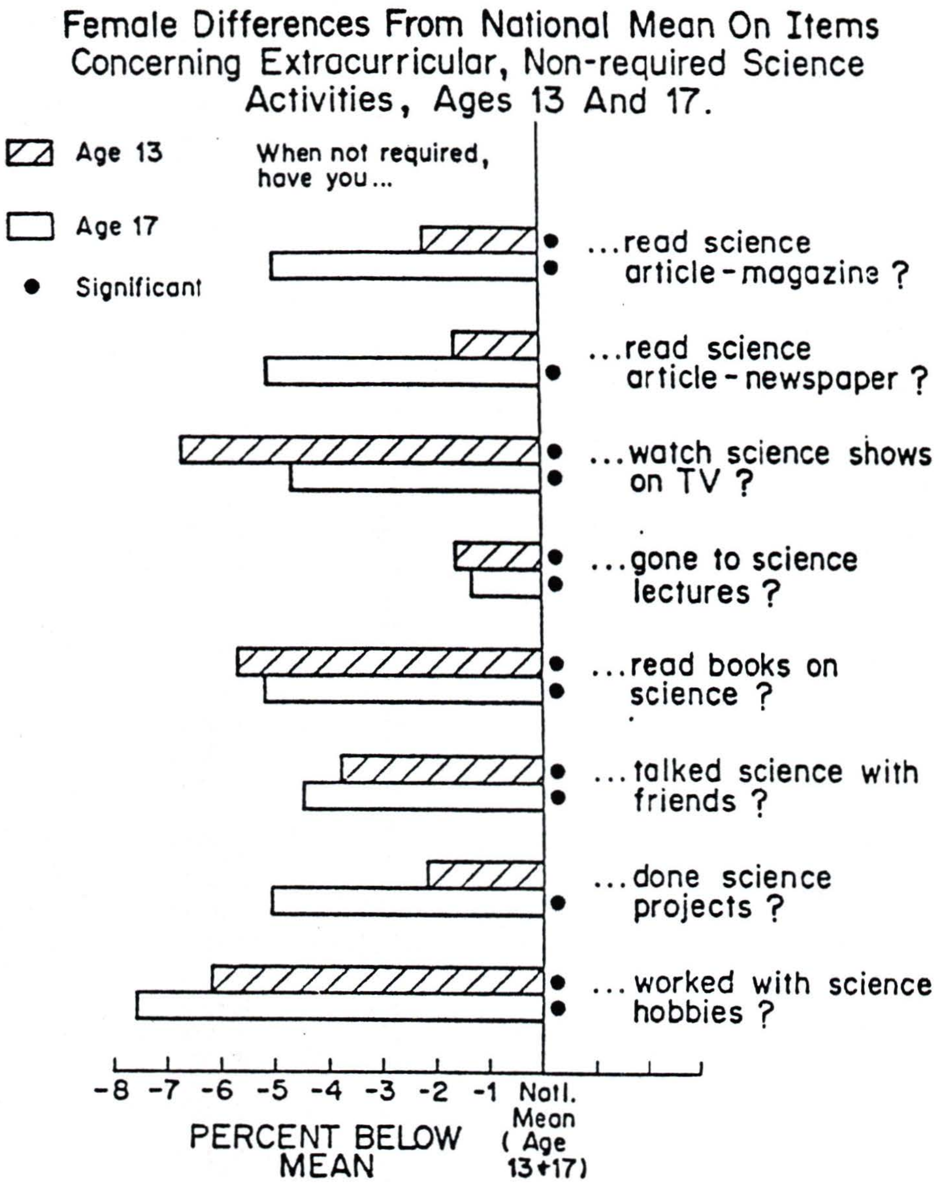


Figure 6

Note. From "Factors affecting female achievement and interest in science and in scientific careers" by M.L. Matyas, 1985, Women in Science, (p. 36), Philadelphia: Falmer Press.

In conclusion, it would seem that well-established gender differences in attitude to and achievement in computer science, mathematics, and the physical sciences exist. These differences are related as pervasive, and seem to affect both formal and informal participation at various age levels. These attitudes towards the "sciences" may well affect the persistence of all students, but particularly female students, in further training for technical careers.

Socio-Cultural Factors

Sex-role stereotyping and role models are the two socio-cultural factors most often mentioned in the literature as influences on gender differences in computing, mathematics, and the physical sciences.

Sex-role stereotyping. A number of researchers have concluded that girls "fear success" in courses perceived as being for boys (Fox cited in Menzies, 1982). As girls tend to rate mathematics (Armstrong,1985; Brush, 1985; Eccles et al., 1985), science (Matyas, 1985a; Wilder, Mackie & Cooper, 1985), and computing courses (Collis, 1985; Hawkins, 1985; Marrapodi, 1984) as being in the "male domain", this fear of success may be particularly evident for females in these three areas. Sex-typing may be negatively related to success and participation. Armstrong and Price (1982) states that "women who did pursue advanced mathematics courses tended not to sex-type mathematics as a subject appropriate for men only." Dale (cited in Matyas, 1985a) has stated that girls who attend single-sex schools see science as being less sex-role stereotyped. In addition, these girls take more mathematics and science courses than girls in coeducational schools.

In their study of students enrolled in advanced placement and accelerated mathematics courses, Casserly and Rock (1985) observed that female students were strongly influenced by what they perceived as appropriate occupational roles for women. For twelfth grade females their sex-typed perception of mathematics seemed to be more influential in setting career goals than either grades in previous mathematics courses or their self-confidence in mathematics.

Role models. The lack of appropriate role models has been cited as an important factor in girls' attitudes to careers in mathematics (Armstrong, 1985; Thomas, 1986), science (Kahle, 1985; Thomas, 1986), and computing (Schubert, 1986). Role models can have a negative effect on girls' attitudes to science if the role model portrays the stereotypic characteristics of the feminine scientist - logical, unfeminine, capable, exact (Ebbertt cited in Matyas, 1985a). In her study of exemplary secondary science and mathematics teachers, of which 86% of the sample were female, Kahle (1985) described the teachers in this sample as enthusiastic, well-qualified in their subject area, knowledgeable about career opportunities, and interested in their students: teachers who were positive role models for their students. These teachers were confident individuals who were aware of sexism in science and strived to eliminate such feelings by providing equitable treatment of female students in the classroom and of female scientists in the teaching materials. Although most of these teachers had science backgrounds, they were not the stereotypic scientist, but were more likely to be warm individuals with strong interpersonal skills and a strong commitment to science teaching; these characteristics seemed to account for the high retention rate of female students in their classes. Likewise, female science undergraduates with female faculty role models had higher degree expectations and indicated increased likelihood of pursuing graduate school compared to female undergraduates without female faculty role models (Seater & Ridgeway in Matyas, 1985b).

While their mathematics teachers played a role in influencing the persistence of females in advanced placement mathematics courses, Casserly and Rock (1985) observed that for twelfth-grade females the presence of friends, particularly those of the opposite sex, in the mathematics class seemed to influence both the student's self-assessment of ability in math and persistence in taking courses. For tenth-grade students the presence of friends tended to influence grades. Same-sex friends seemed to have a positive effect for males while opposite sex friends had a positive effect for female students. Thus, it would seem that peer role models may affect the performance and persistence of students in high school accelerated courses.

Personality Factors

Personality factors are often discussed when gender differences in mathematics and science are being reviewed. The 'women in general can do it but I can not' syndrome has been noted with respect to computers (Collis, 1985) and science (Duncan & Haggerty, 1984).

Gender differences related to personality factors have been noted in several studies. In 1962 Philips (cited in Menzies, 1982) found that males have a higher correlation of IQ and achievement than do girls, and in addition, that girls tend to try to hide their intelligence to a greater extent than do boys. Boys rated their math ability higher than did females, felt that they had to exert less effort than females felt that they had to exert, and held higher expectations than females for future success in mathematics even though there was no difference in past performance between them and the females in the study (Eccles et al, 1985). Boys did not attribute failure to their own ability level as often as did girls, but did attribute success to their own ability more frequently than did girls (Eccles et al, 1985). In contrast, in a study of first-year college science students both males and females were more likely to attribute their success to effort and ability and their failure to course difficulty (Deboer, 1985); this contradiction may be related to the fact that Deboer's sample had all voluntarily enrolled in a first-year science course and hence their overall level of confidence in the material being covered was higher than that of a broader sample of secondary school students. However, Fennema and Peterson (1985) have also noted that females are more likely to attribute success externally and failure internally.

There is some evidence that girls see success in mathematics and science as a threat to their self-image and social image while for boys success in mathematics and science is a positive builder of self-esteem (Kahle, 1985). In science and mathematics courses (Fennema & Peterson, 1985; Smithers & Collins in Matyas,1985) and in computing courses (Kurland & Cahir in Hawkins,1985) female students feel that they are less socially attractive than females who do not enroll in such courses. Gifted girls are "looked down" upon while gifted boys are admired in mathematics and computer science courses (Fox, 1980; Schubert, 1986; Solana in BCTF, 1983).

Personality characteristics often associated with boys --independence, aggressiveness, problem solving orientation, risk taking--are related to those characteristics perceived as necessary to be successful in the sciences (Baird in Morse & Handley, 1985; Kahle, 1985). Frieze and Hanusa (cited in Fennema & Peterson, 1985) report that science is seen as difficult and requiring sacrifice and persistence; scientists are seen as objective, logical, emotionally neutral and as people whose work requires individual effort; they observe that these perceptions are in conflict with stereotypical aspects of the sex-role identity of females. In fact, Ebbertt (cited in Matyas, 1985a) relates that female students are negatively affected by science teachers who portray these characertistics.

However, women taking first-year science courses in at least one study appear to be quite similar to males in personality traits such as persistence, incidence of reckless and rash behaviours, and future orientation (Bachtold in Cooper & Robinson, 1985; Deboer, 1985). The successful female science students in Deboer's study scored significantly higher on persistence and orientation to the future and lower on reckless and rash behaviours than those women who were unsuccessful. However, while women in male-dominated careers score similar to men on masculine characteristics, they also have scores near the norm on "feminine characteristics" such as femininity, supportiveness, passivity, and cooperation (Chusimir, 1983; Leary & Baum in Cooper & Robinson, 1985).

The skills and attitudes involved in working with computers may be perceived of as being more consistent with male personality characteristics than with female characteristics. Computer programming emphasizes the use of rules and logic which may be seen as not fully compatible with socialized female values, such as relational ethics (Gilligan in Lockheed, 1985). Many computer games place emphasis on competition and winning, an emphasis that seems to appeal more to boys than to girls (Lockheed, 1985). Software that requires collaborative work rather than that which is related to mathematical/scientific concepts may be of more interest to girls (Hawkins, 1985). Also, girls show greater interest in word processing and research applications such as data storage and manipulation than boys (Lockheed, 1985) - i.e. practical and useful applications.

While social factors such as sex role stereotypes may negatively influence females' decisions with regard to persistence in mathematics, science, and computer science, the following factors have been shown to be predictors or correlates for women who are choosing to follow a career path towards mathematics, science, and computing:

1. understanding the usefulness of mathematics as a tool (Armstrong, 1985; Armstrong & Price, 1982; Brush, 1985; Eccles et al, 1985; Fennema, 1980; Fennema & Peterson, 1985; Fox, 1980; Rogers, 1985) (See Figure 7 for a summary of Brush's findings)

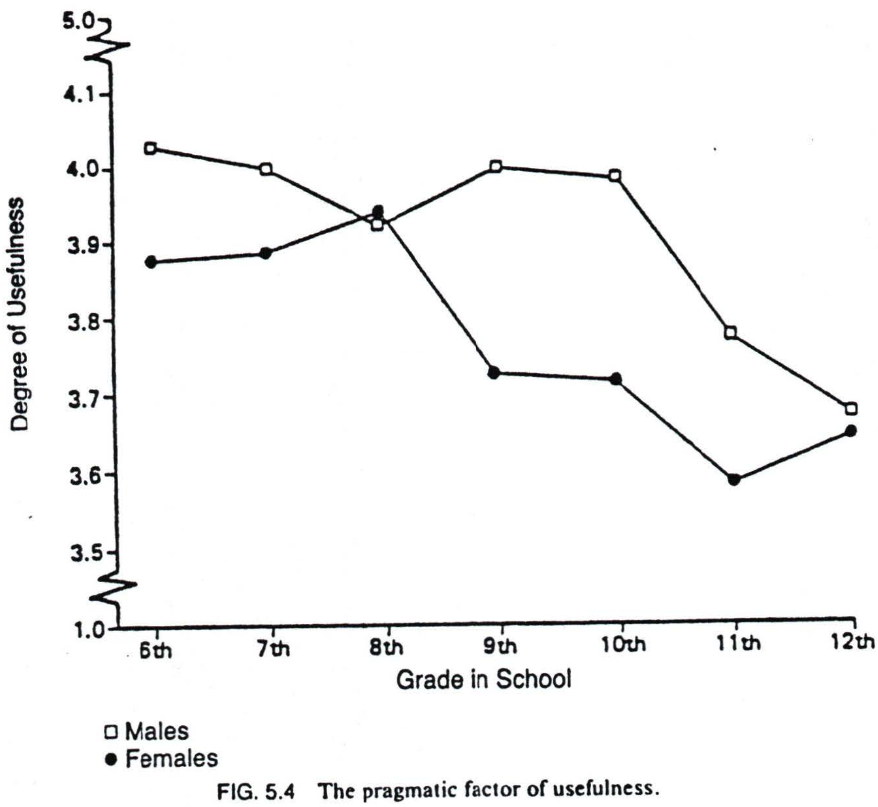


FIG. 5.4 The pragmatic factor of usefulness.

Figure 7

Note. From "Cognitive and affective determinants of course preferences and plans" by L.R. Brush, 1985, Women and Mathematics: Balancing the Equation (p. 139), New Jersey: Lawrence Erlbaum Associates.

2. seeing mathematics as a key to their futures (Fox,1980; Stallings, 1985; Winkle & Mathews, 1982)

3. having experienced positive attitudes of parents (Deptuck, Whelan, & Leuthy, 1985; Menzies, 1982) and significant others (teachers, parents, friends, role models) (Armstrong, 1985; Armstrong & Price, 1982; Sells, 1980; Stalling, 1985; Thomas, 1986; Winkle & Mathews, 1982) (See Figure 8 for Brush's summary)

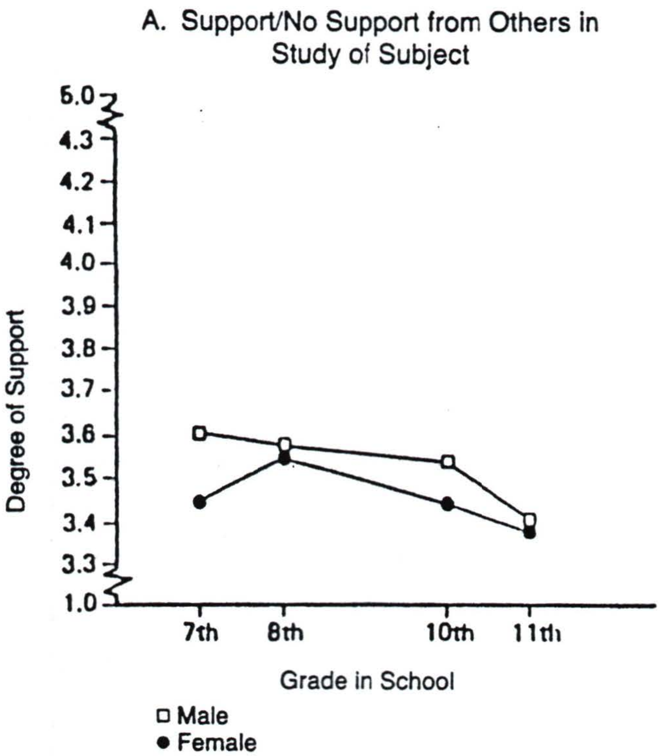


FIG. 5.5 The social factors of encouragement from others and sex-typing of mathematics.

Figure 8

Note. From "Cognitive and affective determinants of course preferences and plans" by L.R. Brush, 1985, Women and Mathematics: Balancing the Equation (p. 140), New Jersey: Lawrence Erlbaum Associates.

4. being interested in science and math (Armstrong, 1985; Thomas, 1986) and in computing (Hawkins, 1985)

5. having positive attitudes towards mathematics (Armstrong, 1985; Armstrong & Price, 1982) and computers (Winkle & Mathews, 1982)

6. achieving in mathematics (Matyas, 1985b; Stalling, 1985; Thomas, 1986; Ware, Steckler & Leserman, 1985)

7. having highly educated parents (Matyas, 1985b; Ware, Steckler, & Leserman, 1985)

8. having a mid to high socio-economic status of student as a factor for computing (Lipkin & McCormick, 1986) and in mathematics (Armstrong,1985; Brush, 1985)

9. having confidence in one's own abilities to do mathematics (Armstrong, 1985; Fennema & Peterson, 1985)

10. having science-oriented hobbies and aspirations in childhood (Thomas, 1986)

11. having access to computers and encouragement in their use (Schubert, 1986).

The extent to which these factors in combination influence persistence in university-level computer science for female students has not yet been systematically examined.

Intervention Strategies

Studies have shown that women tend to make their career choices later than men (Daniels & Lebold in Cooper & Robinson, 1985) and women who choose technical careers are less certain of their vocational choices than are men (Cooper & Robinson, 1985). As noted earlier, career options are determined at a young age by the courses that must be chosen in early teens so students have the required prerequisites later in their academic careers (Smail, 1983). First-year college is another critical time in the final decision of a career path (Ware, Steckler, & Leserman, 1985). Since career options are shaped early in the school career and since females tend to leave their decisions until later, interventions to influence participation in nontraditional careers would seem to be more effective if they were put into effect as early as possible. Interventions have been suggested in several areas.

Awareness

Programs which increase awareness of mathematics as a requirement for future career choices and which confront girls with the misconceptions involved in stereotypic views of math have been endorsed by many as helpful intervention strategies (Sells, 1980). Attitude change is also a focus of intervention programs. Such programs assume that teachers need to instill more self-confidence in female students and provide experiences that will increase female students' enjoyment of mathematics (Armstrong, 1985) and computers (Winkle & Mathews, 1982). Also, since women tend to perceive that severe dedication and hard work are necessary in order to succeed in college science courses, this myth that science is unduly difficult must be dispelled by science educators (Deboer, 1985).

Curriculum

Many are committed to the premise that girls must get a basic core of mathematics and science knowledge as well as computer literacy (BCTF, 1983; Menzies, 1982). Berryman (cited in Kahle, 1985) goes as far as to recommend that "removing choice during high school would perserve it (choice) after high school." Brush (1985) agrees with this observation.

Not only should intervention focus on females' increased involvement in the mathematics, science, and computer science curricula, but these curriculum experiences should also focus on teaching autonomous learning strategies (Fennema & Peterson, 1985; Morse & Handley, 1985). Autonomous learning behaviours are important for the success of any student, but especially for women in mathematics, science, and computer science courses. Autonomous learning behaviours encourage independence and responsibility, build problem solving strategies, build self-image, and through their use provide modelling in problem solving (Fennema &

Peterson, 1985). All of these are suggested as important goals for female students.

Also, with respect to the implementation of curriculum in mathematics, science, and computer science, girls may also do better in a more relaxed classroom atmosphere (Brush, 1985) where textbooks and teaching methods are made more fun and interesting (Rogers, 1985) and where cooperation rather than independent or competitive activity is stressed. These conditions seem to be less important for the success of male students than they are for females. In fact, in the study of Bostock, Seifert, and McArdle (1987) males did not do as well academically and had a higher dropout rate in an adult education computer literacy course when they had to share a computer with two other male students; they had their highest achievement and persistence levels in a traditional one-computer-for-one-student class, but also did better in a class where they shared the computer with female students. In the same adult education course women did better academically and persisted at a higher rate in classes in which they shared a computer with other women and where cooperation was emphasized. Women had their poorest academic results in the classes where they were required to share a computer with a male student. For adult women learning computer use it would seem that all-female classes emphasizing cooperation may be a superior learning environment while for males it would seem that a traditional competitve classroom is the superior learning environment (Bostock, Seifert, & McArdle, 1987).

Finally, the environment surrounding computer use in schools is frequently cited as a target for intervention strategies. Equal access to computers must be provided for males and for females (Dubois & Schubert, 1986) and both genders must be encouraged to actively participate in computer-related activities (Marrapodi, 1984). Computers should be used in a variety of ways in the classroom so that as many children as possible will become interested in their use (Gilliland, 1986a; Hawkins, 1985). Some predict that there will be increased interest and participation by female students if small group activities are used (Gilliland, 1986b; Sanders, 1986). The software used in classrooms should be designed so that girls realize its usefulness for themselves (Hawkins, 1985) and enjoy their experiences with it (Gilliland, 1986b). The software should be checked for "male bias", that is, for sexism or male-oriented reinforcers such as explosions and missile launchings after a certain number correct in a drill program (Marapodi, 1984; Lipkin & McCormick, 1986).

<u>Role Models</u>

Many intervention strategies focus on contact with appropriate role models as a way to encourage involvement in science, mathematics, and computer science for females. Female role models should be brought into the classroom and to "career days" to show the human side of nontraditional jobs. This may influence female students to change their attitudes about charateristics associated with so-called masculine professions (Haring & Beyard-Tyler, 1984; Rogers, 1985). Science and mathematics role models should be brought in contact with potential majors to provide encouragement to them; this seems more important for females who are considering careers in technical fields than for males (Ware, Steckler, & Leserman, 1985).

Effective role models can influence both the attitudes and the achievement of their students. For example, Kahle (1985) found that enthusiastic, well educated, interested teachers of either sex who actively encouraged both male and female students had mathematics and science classes in which males and females performed equally well. Of Kahle's sample of teachers 86% were female; these teachers were female role models to their classes and also provided career information for their students.

Computer-using teachers become the computer-related role models in schools (Stasz, Shalvelson,& Stasz, 1985) and as such must be competent and confident users so that they provide positive modelling (Gilliland, 1986a). Girls in computer classes it seems are more affected and influenced by the apparent competence of the teacher. Schubert (1986) recommends formalized role modelling of computer use through SISCOM, a Big Sister-Little Sister computer programme.

The importance of teachers as role models is stressed over and over in the literature. Teachers must encourage female students to take more mathematics courses and give them career information which shows them the need for such courses (Armstrong, 1985; Armstrong & Price, 1982; Casserly in Eccles & Blumenfeld,1985). They can help to encourage the participation of females through enthusiastic, dynamic, interactive teaching (Armstrong, 1985; Duncan & Haggerty , 1984; Menzies, 1982). They must also encourage girls to persist even when the "going gets tough" (Gilliland, 1986b). Teachers must relay their high expectations to female students as well as to male students in their courses (Armstrong & Price, 1982). Teachers must also be made aware of subconscious biases and behaviours as these affect female attitudes to science and math (Deptuck, Whelan, & Leuthy, 1985). For example, many teachers question and interact with male and female students differently.

In addition, schools and universities should provide workshops and training for elementary teachers to make them more familiar and comfortable with using science activities (Duncan & Haggerty, 1984; Matyas, 1985a), computers (BCTF, 1983; Sanders, 1986), and current up-to-date techniques and information on teaching science and computing (Menzies, 1982). A high proportion of preservice elementary teachers are themselves math anxious; support groups of professional math teachers with an understanding of math anxiety should work with these teachers so that they do not pass their feelings about math onto their students (Kelly & Tomhave, 1985). Teacher training programs should concern themselves with affecting changes in the negative attitudes which many teachers have toward mathematics (Ernest, 1980; Sells,1980) and encourage the teachers to promote nontraditional careers as viable options for their female students (Sells,1980).

Counsellors

Counsellors must be aware of the differences in females' attitudes to computers compared to males' (Collis, 1985) and must try to make female students aware of the usefulness of computers and microcomputers in nonmathematical situations (Collis, 1985). Counsellors must be able to discuss future job possibilities and career appropriateness as well as math anxiety with female students (Menzies, 1982). Counsellors should make girls with mathematics and science potential aware of science as a natural field of study (Ware, Steckler, & Leserman, 1985).

Career exploration programs must become part of the curriculum (BCTF, 1983). The career consciousness of female students must be raised early (Winkle & Mathews, 1985). Workshops on career opportunities and requirements should be held for students, parents, and teachers (Deptuck, Whelan & Leuthy, 1985).

Conclusion

Although many intervention strategies or approaches have been proposed in the general context of female participation in mathematics, science, and computer science, little has been done to specifically improve the persistence of females in computer science at the postsecondary level. The majority of the studies investigating female persistence in computer-related studies and intervention strategies relating to the enhancement of these persistence levels, have related to the secondary school context (Collis, 1985; Sanders, 1986). Intervention strategies such as emphasizing word processing and providing equal access to school computers have little relevance at the college or university level, especially for females who are enrolled in computer science courses. Yet at some institutions at least, the persistence level of females in computer science is markedly lower than that of males.

It can not be assumed that the factors which influence persistence of females at the postsecondary level are the same as those which influenced the interest of females in mathematics, computer science, and the physical sciences at the secondary level. While McCabe and Campbell (1982) looked at persistence in computer science at the postsecondary level, they considered only factors related to academic ability and high school size. They did not take into consideration any of the more affective variables which are observed to be related to interest and participation in the "sciences" at other levels and in mathematics and the physical sciences at the postsecondary level. Effective intervention strategies to improve persistence at this level cannot be planned until there is a greater understanding of how both these affective factors and academic preparation relate to the persistence and nonpersistence of females in computer science at the postsecondary level. When a clearer picture of factors discriminating between persistence and nonpersistence in computer science is available, it will be easier for professionals responsible for such programs to design a more adequate curriculum and for counsellors to advise females in a more informed manner. Thus, in this study models for predicting persistence in computer science at the postsecondary level by males and females will be studied to determine if gender differences in persistence do exist at this level of computer science education and if so, how they differ. This, in turn, will support recommendations for improving persistence for females in first-year computer science.

CHAPTER 3

Development of the Path Analysis Model for Persistence in Computer Science

Men are more likely to persist in the study of computer science than women (Campbell & McCabe, 1982). This study will address the issue of how this difference develops by estimating and comparing path analytical models of the process of persistence in computer science for males and females. Age, predicted success in first-year university-level computer science, previous computer science courses, "comfort level" in first-year university-level computer science, previous experience in computer use (not course related), tendency to stereotype, attitude to mathematics, and achievement in first-year university computer science will be factors considered in this model for predicting persistence in computer science and for identifying gender differences in persistence. To test for sex differences in persistence in computer science, the model will be estimated separately for male and female students, and comparisons made between corresponding path coefficients.

Theory of Path Analysis

Path analysis is a useful method for testing models developed on the basis of knowledge and theoretical considerations. Mueller, Schuessler, and Costner (1977) relate that to formulate the causal assumptions constituting a path model one must use prior information and "common sense" reasoning to designate the causal ordering of the variables and to propose the path or paths by which each variable has its presumed effects on variables which come after it in the proposed model. The path analysis model relates not only the causal ordering of the variables, but also takes into account both direct and indirect relationships by which variables affect each other.

Path models can be represented by path diagrams or by a set of equations. The path diagram seems easier to understand as it gives a pictorial view of the paths by which the variables affect each other. The equations relate the linear dependence of the variables and express the error term or residuals for each path. While the equations are essential to path analysis, the diagram presents the model more clearly by showing sequences and paths visually.

In a path model variables are separated into two types: exogenous and endogenous. Exogenous variables are those variables whose variation is assumed to be related to causes outside the model. Endogenous variables are those variables whose variability is explained, at least in part, by other variables in the model. A residual term is also included in the model. The residual term relates the amount of the variation in an endogenous variable which is not accounted for by the model. Figure 9 is a path diagram which illustrates a model with two exogenous variables numbered 1 and 2 and two endogenous variables numbered 3 and 4. The residual terms are indicated by the labels U and U .

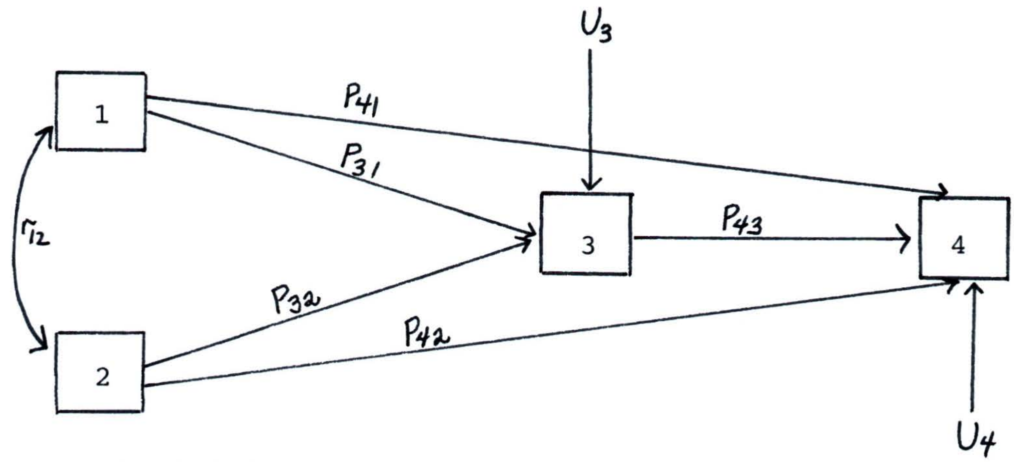


Figure 9. A Path Diagram

Although exogenous variables are assumed to have causes outside the model, a correlation between exogenous variables may exist. This correlation is indicated by a curved line with arrowheads at both ends linking those variables. This arrow indicates covariance, but this covariance will not be discussed in the present path model. In Figure 9, the covariance between the two exogenous variables is indicated by the symbol, r12.

Dependence between variables in the model is indicated by straight unidirectional arrows. In Figure 9, this dependence is illustrated by five path coefficients. The path coefficient p31 illustrates the effect of Variable 1 on Variable 3. The models tested in this study will be recursive; that is, no feedback effects between a pair of variables will be considered. For example, attitude to mathematics will be indicated as affecting achievement in computer science; however, the effect of achievement in computer science on attitude to mathematics will not be considered.

Kerlinger and Pedhazur (1973) relate that the following assumptions underlie the application of path analysis:

(1) The relations among the variables are linear, additive, and causal.

(2) Error terms (residuals) are not correlated with each other, or with variables preceding them in the model. This assumption implies that all relevant variables are included in the model. Endogenous variables are dependent on linear combinations of exogenous and/or other endogenous variables and a residual term.

(3) The relationships are recursive, that is, unidirectional.

(4) The variables are interval variables. However, some researchers have developed methods in which the variables can be measured on interval, ordinal, or categorical scales. The method by which the path coefficients are calculated depends on the type of variable. The use of point-serial correlations between interval and categorical variables and phi coefficients between two categorical variables is suggested. However, Nunnally (1978) points out that point-serial and phi correlations are indeed only special cases of the product-moment correlation and as such result

in exactly the same numerical results as would be obtained for Pearson's product-moment correlation. Thus, when one uses a computer to calculate these correlations no distinction must be made for the calculations. The use of the different types of correlations is the only change made in the path analysis procedure with categorical variables.

When using path analysis to develop a model which will be tested with the data collected during the study, one begins with a fully recursive model. In this fully recursive model, each variable is directly influenced by all the variables which precede it in the postulated causal order. After the fully recursive model is developed, the path coefficients for some paths are hypothesized to be zero so that the most parsimonious model can be formulated. The deletion of paths may differ for the different groups being tested. In this study the paths may differ by gender or the model may predict different strengths for the path coefficients on the various paths.

However, Kerlinger and Pedhazur (1973) emphasize that the crucial point of model testing is that "the theoretical formulation is not derived from the analysis" (p. 317). The analysis indicates whether or not the relationships which exist in the data are consistent with the theoretical model. They also emphasize that although causation is implied in the path model, correlation is not causation. Path analysis is simply a way in which data can be compared to theory.

Calculation of Path Coefficients

Although a path diagram gives a visual representation of the relationships in a model, the equations for the paths are necessary for the computation of the path coefficients, which give a numerical representation of the strengths of the paths. The following equations represent the relationships which were illustrated in the path diagrams in Figure 9:

$$z_1 = u_1$$

$$z_2 = u_2$$

$$z_3 = p_{31} z_1 + p_{32} z_2 + u_3$$

$$z_4 = p_{41} z_1 + p_{42} z_2 + p_{43} z_3 + u_4$$

The equation for a variable has terms related to variables on which it is dependent and a term representing its residual. Because exogenous variables are assumed to be dependent on factors outside the model, they are represented by a residual term only. The endogenous variables have terms related to both the exogenous and endogenous (if any) variables antecedent to them in the model. Values for these path coefficients are calculated using correlations between the exogenous variables and the standardized betas from regression equations for each of the endogenous variables in the models. Fox (1980) developed a simplified procedure for calculating path coefficients. A computer program using Fox's procedure will be used to calculate path coefficients in this study.

Fox's procedure decomposes the path coefficients into the following components: direct effects, indirect effects, unanalyzed effect due to correlated causes, and spurious effects due to common causes. In the path diagram shown in Figure 9, Variable 1 has a direct effect on Variable 4 along the path p41 and an indirect effect on Variable 4 as mediated by Variable 3 along the path p31p43. The sum of the direct effect and the indirect effect is called the total effect or effect coefficient. Fox (1980) refers to the sum of the unanalyzed effects and the spurious effects as the noncausal part of the correlation. Depending on the causal model, a variable may have only an indirect effect on another variable (Pedhazur, 1982). The coefficients calculated depend on the relationships indicated in the path model; thus, it is important that the model accurately represents the theoretical formulation underlying the variables.

Testing the Fit of Causal Models

The purpose of this study and indeed most studies which use path analysis as a statistical tool is to determine how well the hypothesized model fits the data from a real situation. Several methods have been developed to test the goodness-of-fit for causal models. Most tests for goodness of fit involve the comparison of the fully recursive or "just-identified" model in which all the variables are interconnected with the "overidentified" or hypothesized model in which the direct effects between certain variables have been predicted to have zero coefficients. Pedhazur (1982) warns that models being tested must be based on theory and warns against a "proliferation" of overidentified models in search of one which best fits the data.

Specht (1975) developed a goodness-of-fit test in which a W-statistic is calculated. This W-statistic is evaluated as with degrees of freedom equal to the number of paths eliminated in the overidentified model. To determine W it is first necessary to calculate R_m^2, a generalized squared multiple correlation, for the fully recursive model:

$$R_m^2 = 1 - U_1^2\ U_2^2\ U_3^2\ ....U_n^2$$

where U_i is the residual for a path in the fully recursive model. Next, an analogous statistic, M, must be calculated for the hypothesized or overidentified model:

$$M = 1 - U_1^2\ U_2^2\ U_3^2\ ....U_n^2$$

where U_i is the residual for a path in the overidentified model.

R_m^2 can have values between zero and one while M can have values between zero and R_m^2. The closer M is to R_m^2 the better the fit of the overidentified model. Specht's measure of goodness-of-fit for an overidentified model is:

$$Q = \frac{1 - R_m^2}{1 - M}$$

Using the Q value a χ^2 statistic can be determined using the equation:

$$W = -(N - d) \ln Q$$

where N equals the sample size and d is the number of paths eliminated in the overidentified model. For large samples the W statistic is evaluated as a χ^2 statistic with degrees of freedom equal to d. If the model is a good fit the statistic will not be significant and the model will be retained. The W statistic is very dependent on sample size; large sample sizes will result in large W values which, in turn, may result in rejecting a model which fits the data well while small sample sizes may result in retaining a model that does not fit the data well. Thus, the W statistic must be interpreted with great care (Pedhazur, 1982). It is suggested that interpretation of the Q statistic and the change in the residual terms from the fully recursive model to the hypothesized model may be a better approach to take when interpreting the goodness-of-fit of the model. The closer the Q statistic is to the value 1 the better the fit of the model.

Pedhazur (1982) also notes that path coefficients derived using the computer program designed by Fox are based on standardized beta weights and as such are scale-free but sample-specific. Thus, they cannot be used to compare populations. Since path analysis is based on multiple regression, the same sources of error--sampling errors, measurement errors, high multicollinearity, and specification errors--must be considered. In addition to these considerations related to multiple regression both Pedhazur (1982) and Specht (1975) caution researchers using path analysis to test a model based on the theory and not to become involved in "post hoc theory trimming." Hence, once a model which incorporates all the pertinent variables has been developed based on the theory, this model should be tested using the path analysis procedure and then retained or rejected based on its merits without post hoc trimming. Thus, the following discussion begins by indicating the rationale for the models for persistence of male and female students in first-year computer science courses that will be subsequently tested and discussed in this study.

Development of the Models

The first step in the use of path analysis for theory testing is the development of the causal model which is based upon the review of the literature and knowledge related to the field. In this study the models will include four exogenous variables--age, previous computer courses (high school or university), previous computer use, and attitude to mathematics; and five endogenous variables--tendency to stereotype computer use and users, "comfort" level in Computer Science 110 (the first-year computer science course at the University of Victoria), prediction of success in Computer Science 110, achievement in Computer Science 110, and persistence in computer science. Persistence in computer science will be measured by whether or not students who in September indicated that they intend to or expect to enrol in the subsequent Computer Science 115 or 160 course actually did enrol in the course in January. Each of these variables will be described and defended later in this chapter.

Figure 10 illustrates the fully recursive model which incorporates the nine variables mentioned previously. Each of Variable 5 to 9 is assumed to be dependent on all variables which appear before it in the model. The justification for these assumptions will also be developed in this chapter.

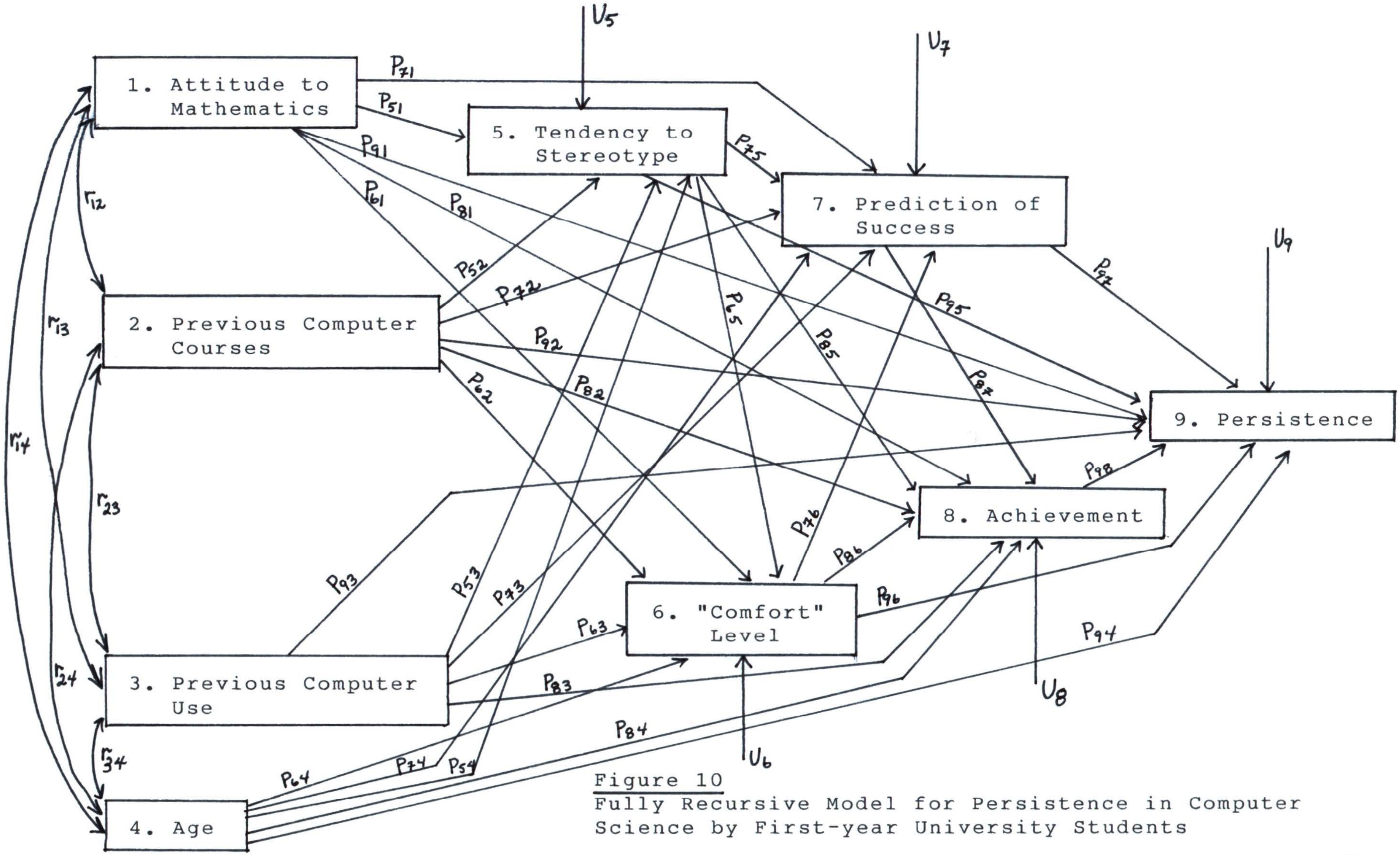


Figure 10
Fully Recursive Model for Persistence in Computer Science by First-year University Students

Given the fully recursive model in Figure 10 each path has been labelled using the convention common to path analysis. Thus the path coefficient, p51, represents the relationship showing the effect of attitude to mathematics, on the "cause", tendency to stereotype computer science. The following discussion is intended to justify the fully recursive model and explain why certain paths in the fully recursive model will be eliminated in the models for persistence in computer science for male and female students. Paths in the model are eliminated by setting their path coefficients as zero. Following this discussion, the hypothesized models for males and females will be summarized and displayed graphically. As was noted earlier, the fully recursive model for persistence in computer science consists of four exogenous variables and five endogenous variables. The inclusion of these variables in the model as well as the ordering of the endogenous variables in the models are supported by prior research in computer science or by certain relationships which have been indicated by research in related fields.

Exogenous Variables

Attitude to mathematics. Thomas (1986) related that participation in mathematics and science at the postsecondary level is related to the attitude of the students to these courses. Armstrong and Price (1982) observed that there is a correlation between a positive attitude to mathematics and participation in more mathematics courses. Males tend to have a more positive attitude to mathematics, science, and computers than do females (Collis, 1985; Duncan & Haggerty, 1984; Simpson & Oliver, 1985; Smail, 1983). However, Wilder, Mackie, and Cooper (1985) observed that attitude to mathematics and computers seemed less important for males entering a college-level computer programming course than it was for females. While attitude to mathematics seems an important variable in participation in further technical training, it would seem to be more influential for females than for males. Thus, attitude to mathematics is included as an exogenous variable in the path model for females, but is not included in the model for males.

Previous computer courses. It would seem logical that previous study of computers would influence the attitude of students to computers and their participation in further computer training. Indeed, this view was supported by Greer's (1986) study of students registered in introductory computer science courses at the University of Saskatchewan. Participation in high school computer science courses was positively related to the persistence of students in introductory computer science at the university level, but in general, students who had taken high school computer science did not achieve better grades in the university-level courses than those of students who had not taken computer science in high school.

Computer science courses at Grade 11 and Grade 12 in British Columbia introduce students to a variety of computer applications including computer programming which is a focus of the first-year computer science course at University of Victoria. However, there seems to be an ambivalent feeling on exactly what effect these courses have on the performance of first-year students in computer science and on their persistence in further courses. Since debate occurs on whether high school computer science courses should be made prerequisites to Computer Science 110, whether advanced placement for students with Computer Science 12 should be given, and whether high school computer science courses result in poor programming skills which must be retaught at the university level, it is important to focus on the effects of previous formal computer courses on persistence and achievement at the first-year level. Thus, the previous computer courses variable is retained in both the male and female models.

Previous computer use. Girls seem to have more limited access to computers in the higher grades than do males (Hawkins, 1985; Lipkin & McCormick, 1986). Sanders (1986) and Kahle (1985) relate that high school age males report more extensive extracurricular computer use than do females of the same age. Greer (1986) indicated that extensive computer experience at the high school level has an effect on the withdrawal rate of students registered in introductory computer science courses at the university level; however, Greer did not investigate gender differences in his study. Hence, how this difference in prior computer experience may indeed affect the feeling with which female students approach computer science courses as well as their participation and persistence needs to be investigated. Also with the proliferation of microcomputers in society today, it is important to test whether formal computer courses or just "any" computer use influences persistence and achievement at the postsecondary level. Thus, previous computer experiences are retained in both the male and female models.

Age. In discussion with members of the Computer Science department at the University of Victoria, the age of students was a factor which they perceived influenced persistence in computer science. Cooper and Robinson (1985) relate that males and females tend to make career choices and decisions at different ages. Thus, the effects of age on the endogenous variables is a consideration in this study and age is retained as a variable in both the male and female persistence models.

Correlations may exist between exogenous variables; however, such correlations are outside the model and will not be explained by the model. It is predicted that a positive correlation between previous computer courses and previous computer use and a negative correlation between age and previous computer courses will exist for both males and females. A positive relationship between attitude to mathematics and previous computer courses may exist for females.

Endogenous Variables

Stereotyping computer science. Stereotyping computer science as "male appropriate" has been indicated as a possible factor which negatively influences the presence of females in computer science. Thus, stereotyping of computer science has been included as a factor in the model for females but not for males. In a related study of Computer Science 110 students at the University of Victoria, Connors (1987) observed that responses to a battery of survey questions connected with stereotyping of computer science could be represented by three factors: a "people" skills factor, a math-related factor, and a science-related factor. The university students enrolled in Computer Science 110 differed significantly from the computer professionals on the "people" skills factor in that the students were more likely to endorse a stereotype of computer users as not having or needing good communication and social skills. Therefore, in this study, the factor scores on the "people-skills" factor obtained in the previous study will be used as a measure of stereotyping. The derivation of these scores will be discussed more fully in the Instrumentation section.

In the fully recursive model (Figure 10) the variable, tendency to stereotype computer science, could be influenced by all four of the exogenous variables which come before it in the model. Hence, there are four path coefficients related to stereotyping computer science.

The first path coefficient p51 indicates the effect of attitude to mathematics on stereotyping of computer science. In the review of the literature, it is observed that female students, who generally have a less positive attitude to mathematics (Duncan & Haggerty, 1984; Smail, 1983) tend to stereotype computer science as being more male-appropriate than do male students (Collis,1985; Hawkins, 1985; Marrapodi, 1984). Sex-typing may be negatively related to success and participation (Armstrong, 1982). Thus, this path p51 is important for females who tend to sex-type computer science, but would not seem to influence the participation of male students who are less likely to feel that computer science may be an inappropriate career for them and who also tend to have a more positive attitude to mathematics.

The path coefficient p52 relates the effect of previous computer science courses on the tendency to stereotype computer science. In the field of mathematics, it has been reported that females who have taken more higher level mathematics courses are less likely to stereotype mathematics as male-appropriate than are females who have not taken higher level mathematics courses (Armstrong, 1982; Casserly & Rock, 1985). Connors (1987) in a related study observed that females in a first-year computer science course were less likely to endorse the stereotypes on the "people" factor than were a sample of female students at the same university who were not studying computer science. Hence, it would seem that this path is not important for either male or female students taking computer science at the first-year university level as the females have already decided to pursue postsecondary computer science level courses and they would not seem to be hindered by the possession of stereotypes such as those associated with this factor. Thus, the path coefficient p52 is assigned a zero coefficient for both the male and female models.

The effect of previous computer experience on the tendency to stereotype computer science is shown by the path coefficient p53. As with the influence of previous participation in computer science courses, it is not presumed that actual prior use of computers has a direct influence on the tendency to stereotype computer use or users.

The path coefficient p54 relates the effect of age on the tendency to stereotype computer science. In Connor's (1987) study there was no significant gender difference between the level of stereotyping of computer science by students enrolled in Computer Science 110 in the 1986/1987 academic year at the University of Victoria. However, there was a significant difference on the tendency to stereotype on the "people" factor between the generally younger first-year computer science students at the university and the older students enrolled in comparable computer science courses at British Columbia colleges, with the younger university students being more likely to stereotype computer science than were the older college students. Thus, age may indeed have an effect on the tendency to stereotype; however, this relationship was not extensively pursued in the previous study. Since age has been discussed as a possible significant factor for female students with respect to persistence in computer science by department personnel at the University and females are more likely than males to sex-type activities or persons, the effect of age on tendency to stereotype will be included as a factor in the model for females. It is predicted that the path coefficient will be negative for female students indicating that as age increases there is less likelihood of stereotyping computer science by the female student.

Comfort level. The extent to which students feel that they belong in a class as well as the degree to which they can relax and enjoy a class would seem to influence their academic success in a course (Kahle, 1985). Likewise, it seems logical that if a student is uncomfortable and does not enjoy a particular class, it is less likely that he or she would continue to study similar courses. Thus, the "comfort" level of students in Computer Science 110 was measured using questions relating to atmosphere in the lectures and laboratories associated with that course as well as with a measure of the extent to which the students felt personally comfortable in the Computer Science 110 course. Thus, comfort level was included in the fully recursive model for persistence in computer science. The comfort level variable can be affected by the endogenous variable, stereotyping computer science, which precedes it in the model, as well as the four exogenous variables.

The path coefficient p61 relates the effect on comfort level influenced by attitude to mathematics. In general, female students at the high school level had less positive attitudes to mathematics than did male students (Duncan & Haggerty, 1984; Simpson & Oliver, 1985). It would seem that this more negative attitude may indeed influence how female students feel about their computer courses. Any feeling of fear or inadequacy in mathematics may affect how students feel in a course which they perceive as being mathematics related. This perceived relationship between mathematics and computing has been observed by several researchers (Hawkins, 1985; Lipkin & McCormick, 1986; Lockheed, 1985; Winkle & Mathews, 1982). Thus the path p61 would seem to be important for females, but not a concern for males in first-year computer science and was therefore retained only in the female model.

The effect of previous computer science courses on the comfort level in Computer Science 110 is expressed by the path coefficient p62. In their study of first-year college students, Wilder, Mackie and Cooper (1985) related that females with extensive programming experience at the high school level gave responses which indicated that even with their previous computer courses they felt uncomfortable in the first-year college computer science courses. These females with extensive experience in previous computer courses and use were less comfortable in their computer class than males who had no previous computer courses or experience using computers. Thus, the path coefficient p62 would seem important for females, but not for males. Likewise, Wilder, Mackie, and Cooper's (1985) observation would also seem to indicate that the path coefficient p63 which relates the effect of previous computer use on the comfort level in Computer Science 110 should be retained for females, but not for males.

The path coefficient p64 represents the relationship between comfort level in computer science and age. In discussion with personnel from the Computer Science Department at the University of Victoria, some members observed that older female students seemed to persevere with and to express a more positive attitude to their studies than did younger female students. This may indicate a possible relationship between age and comfort level for female students; hence, the path coefficient p64 is considered to be non-zero in the model for female students. As no similar relationship was expressed for male students, this path coefficient p64 is considered to have a zero value in the male model.

The effect of the tendency to stereotype computer science as being more "male" appropriate on the comfort level felt by the student in computer science is expressed by the path coefficient p65. Brody and Fox (1980) related that girls "fear success" in courses which they stereotype as being more male appropriate; however, this does not necessarily imply that the female students will feel uncomfortable in the computer science classroom. Although unequal or sexist treatment in the classroom could also affect the comfort level and performance of female students in science and mathematics courses (Brophy, 1985; Fennema & Peterson, 1985; Kahle, 1985; Morse & Handley, 1985), there is no indication in these studies that sex-typing by the student affects their personal feelings in a course. Thus, the relationship between tendency to stereotype computer use and comfort level would seem to be a zero-coefficient path for both females and males.

Prediction of success. Prediction of success in mathematics and science courses has been used as a measure of self-confidence by both Casserly and Rock (1985) and Mura (1987). Thus, in this study a variable which reflects the student's confidence level in computer science as measured by a prediction of success in the Computer Science 110 course has been included in the path analytical model as a potentially important variable. Self-confidence in the subject matter being covered may be related to persistence in the subject. Casserly and Rock (1985) observed that for males their positive self-assessment and self-confidence which resulted from simply being in the advanced placement mathematics courses may be sufficient to encourage their persistence while lack of self-confidence may adversely affect the persistence of females. Thus, prediction of success in Computer Science 110 is incorporated into the causal model as a variable that potentially influences achievement and persistence in computer science of both male and female students, but which can itself be influenced by the four exogenous variables--attitude to mathematics, previous computer courses, previous computer experience, and age as well as the two endogenous variables--tendency to stereotype and comfort level, that precede it in the model.

The path coefficient, p71, corresponds to the effect of attitude to mathematics on the prediction of success or self-confidence in the first-year computer science course. Armstrong and Price (1982) related that female students with a positive attitude to mathematics were more likely to participate in further mathematics courses while Thomas (1986) observed that a positive attitude to mathematics correlated with participation in further mathematics and science training. Since attitude to mathematics seems to be a more important influence on persistence for females than it is for males, it would seem that attitude to mathematics may affect self-confidence in computer science for females but not for males. Thus, the path indicating the effect of attitude to mathematics on prediction of success is retained for the female model but not in that for males.

The effect of previous computer courses on self-assessment of ability in computer science is shown by the path coefficient p72. In their study of advanced placement mathematics students, Casserly and Rock (1985) observed that of all the factors studied, grades in previous mathematics courses had the strongest influence on the student's prediction of success in his or her advanced placement mathematics course. Since there seems to be parallels between relationships which exist within mathematics and those which exist within computer science, this path is included as a non-zero path for both the male and female models.

The path coefficient p73 relates the effect of previous computer use on the prediction of success in first-year university level computer science. In general, female students in secondary schools seem to show less interest in extracurricular computer activities such as computer camps and video games (Hess & Miura, 1985; Lockheed, 1985). Males report having more extensive opportunity for computer use both formally in courses and informally as a free-time activity (Hawkins, 1985; Sanders, 1986). Thus, it would seem that the effect of previous computer use on their self-assessment of success in Computer Science 110 would be a factor for males, but would probably not be a factor for females.

The path coefficient p74 represents the effect of age on the prediction of success in Computer Science 110. No indication of a relationship between age and prediction of success has been found in the literature. Thus, this path has not been retained for either the male or the female model.

The effect of the tendency to stereotype computer science on self-confidence in Computer Science 110 is represented by the path coefficient, p75. Boswell (1985) relates that the tendency of women to stereotype mathematics as more male appropriate may adversely affect their self-esteem when they participate in mathematics courses. This may bring about a perception of themselves as less competent in mathematics. Thus, this path would seem to be important in the path analytical model for women. However, Boswell (1985) reports that stereotyping mathematics did not seem to affect the perceptions of males as related to their abilities and participation in mathematics. Thus, this path would seem to be a zero-coefficient path in the path model for males.

The path coefficient, p76, relates to the effect that the student's comfort level in Computer Science 110 seems to have on his or her prediction of success in the course. For students enrolled in twelfth-grade Advanced Placement Calculus courses, Casserly and Rock (1985) report that having friends in the class which would seem to give one a more positive feeling about the atmosphere in the classroom correlates with the self-assessment of performance in the course. Female students seem to be more deeply affected by the type of teacher and the classroom atmosphere than male students enrolled in secondary science courses (Kahle, 1985). This would seem to indicate that how the female student feels about the classroom situation is more likely to influence self-confidence about the course than would be the case for male students. Hence, the path p76 relating comfort level and prediction of success would be included in the female model but would not be included in the male model.

Achievement. The achievement level attained by students in their first university-level computer science course has been shown to correlate strongly with their persistence and success in computer science, engineering, and science degree programs (Campbell & McCabe, 1982). Thus, achievement in

Computer Science 110 would seem to be an important variable in the path analytical model for persistence in computer science. While achievement is an endogenous variable which may affect persistence in computer science, it may be affected directly or indirectly by all the variables--exogenous and endogenous-- which precede it in the model.

The effect of attitude to mathematics on the achievement level in Computer Science 110 is shown by the path coefficient p81. Achievement in computer education has often been related to achievement in mathematics (Hawkins, 1985; Lipkin & McCormick, 1986; Lockheed, 1985); however, the previous research does not seem to link achievement in computing at any level directly with attitude to mathematics for either sex. Although an indirect link between attitude to mathematics and achievement in computer science may exist, it would seem to be appropriate to assign zero coefficients to this path for both male and female students.

The path coefficient p82 relates the effect of having taken previous computer courses on the achievement level in Computer Science 110. In their synthesis of the literature related to mathematics participation and achievement, Chipman and Wilson (1985) observed that success in previous mathematics courses seems to be one of the best predictors of success in later mathematics courses. The correlations seemed slightly stronger for males than for females.

Campbell and McCabe (1982) and Peterson and Howe (1979) indicted a relationship between high school science and mathematics courses and success in first-year computer science. However, Greer (1986) relates that in his study of undergraduates studying introductory computer science courses there was no relationship between high school computer science courses and achievement in introductory computer science courses at the university level. Greer's study did not address the possibility of gender differences in achievement and high school computer science relationship. Hence it seems important to examine this relationship between previous computer courses for both males and females to see if there is a relationship for this sample and to see if there is any gender difference.

Furthermore while the literature suggests that a relationship between previous computer courses and achievement may exist, the nature of this relationship has long been discussed. Some computer science educators seem to feel that previous programming courses are beneficial to students entering postsecondary computer science training; others feel that what is taught at the high school level in some school systems may actually result in postsecondary institutions having to help the student "unlearn" and then re-learn some concepts. Thus, it would seem that this is a crucial variable in the study on its own merit as well as a factor in persistence. For these reasons, p82 is retained in both the male and female models.

The effect of previous computer use on achievement in first-year computer science is represented by the path coefficient p83. The ability to use a computer whether to program or simply to use it as a tool for preprogrammed processes would seem to influence the ease with which a student would learn further computing processes. The increased access to computers outside the formal computer science classroom means that more students are entering introductory computer science courses with previous computer experience. This raises the question of whether this computer experience which may have been acquired on the job, at home, or through courses and which may or may not involve programming skills does affect the student's achievement level in his or her first university-level computer science course. Thus, this path will be retained in both the male and female models for investigative reasons; however, since male students seem to have greater opportunity for access to computers and computer activities (Hess & Miura, 1985; Kahle, 1985) it is predicted that this path will be stronger for males than for females.

The effect of age on achievement in computer science, p84, has been discussed with members of the Computer Science Department at the University of Victoria. In their experience it seems that age has little direct relationship with achievement in computer science. Thus, this path is not retained in either the predictive model for females or males.

The path coefficient p85 represents the effect of the tendency to stereotype computer science on the level of achievement, that is, on the grade received in Computer Science 110. Boswell (1985) reports a negative correlation between stereotyping of mathematics and achievement scores in mathematics courses; however, in their synthesis of the literature, Chipman and Wilson (1985) relate that stereotyping mathematics as male appropriate does not seem to be a good predictor of success in mathematics courses. Thus, it would seem that sex-typing technical subjects may only indirectly affect achievement in related courses. As a result, the path p85 is not included in the model for either males or females.

The effect of personal comfort level in the Computer Science 110 lectures and labs on the achievement level in that course is represented by the path coefficient p86. Little reference is made to the influence of comfort level on achievement in the literature. Casserly and Rock (1985) observe that having friends in accelerated mathematics classes seemed to influence grades for tenth-grade students. However, by twelfth-grade this relationship between presence of friends and grades did not seem to exist; the presence of friends at the twelfth grade level did seem to be related to self-assessment and persistence. It may be that as students mature, the atmosphere in the classroom may have less influence directly on grades, but still may be a factor in the student's affective decisions with regards to further participation. Thus, the path coefficient p86 which represents the direct influence of comfort level on grades in Computer Science 110 has been assigned zero coefficients for both the male and female models.

The path coefficient p87 relates the effect of prediction of success in Computer Science 110 on actual achievement in Computer Science 110. While achievement in previous mathematics courses is related to prediction of success in a present mathematics course (Casserly & Rock, 1985), there is no indication that a positive prediction of success relates to actual grades received in the present course. However, Wise (cited in Chipman & Wilson, 1985) observed that for women self-confidence had some association with mathematics achievement. In the same article, data from a study by Fennema and Sherman reveal a relationship between confidence and grades, but this relationship is not sufficient to influence the achievement level when participation in previous courses is also considered. Thus, it would seem that prediction of success, as a measure of self-confidence, may have an indirect effect on achievement, but may not be directly related. Hence, p87 is a zero-coefficient path in the models being tested.

Persistence. Prediction of variables related to continued participation in computer science is the basic problem being investigated in this study. In the fully recursive model, persistence in computer science is affected by the four exogenous variables--attitude to mathematics, previous computer courses, previous computer use, and age--as well as by the four endogenous variables antecedent to it in the model--tendency to stereotype computer science, comfort level in Computer Science 110, prediction of success in Computer Science 110, and achievement level in Computer Science 110. These variables may directly or indirectly affect the persistence of students in the study of computer science.

The path coefficient p91 represents the effect of attitude to mathematics on persistence in computer science by students after they have completed a first-year computer science course. Bactold (cited in Cooper & Robinson, 1985) and Deboer (1985) both relate that women who are successful in first-year college or university-level science courses appear to be quite similar in personal traits and characteristics to males enrolled in these courses. Thus, it may be that by this level of study attitude to mathematics, although an indirect factor, most likely does not directly affect a student's decision to continue on to further computer science courses. Hence, the path coefficient p91 is assigned a zero value for both the male and female models.

The effect of computer courses taken prior to enrolling in Computer Science 110 on persistence in computer science is shown by the path coefficient p92. In his study of undergraduates who had attended high schools where computer science courses were taught and who were now enrolled in an introductory computer science course, Greer (1986) reports that students who had taken a computer science course or courses at the high school level were more likely to persist in the university-level computer science course than were those students who had the opportunity but opted not to take computer science in high school. Greer's study did not address gender differences in persistence in computer science. Previous computer science courses may affect the persistence of male and female students to a different degree as males are more likely to attribute their success in courses internally and their failures externally than are females while females have a greater tendency to blame their failures on their own ability (Eccles et al., 1985; Fennema & Peterson, 1985). Thus, even limited success in previous courses may give male students the confidence to continue in computer science, regardless of how well they do in Computer Science 110. As related by Ware, Steckler, and Leserman (1985) in their study of undergraduates with science majors, females will take their success or failure in Computer Science 110 as a greater measure of their ability in computer science than success or failure in their previous computer courses, but may still be influenced to a certain extent by their previous courses. Thus, the path coefficient p92 is retained for both males and females as a non-zero coefficient while it is assumed that this path will be stronger for males than for females.

The path coefficient p93 represents the effect of previous computer use on persistence in computer science. Greer (1986) relates that students who have previous computer experience are less likely to be overwhelmed by the vast quantities of information presented in the introductory computer science course to the point that they withdraw from the course compared to students who have little or no computer experience. In fact, he predicts that "the students with lower ability who had high school computer experience were potentially more likely to complete the course and achieve lower examination scores, while lower ability students with no experience were more likely to withdraw" (p. 223). As with previous computer courses, the ability to use a computer may give students sufficient confidence to continue in their pursuit of a computer science career. Thus, this path is retained in the model for males and females, but it is predicted to be stronger for males than for females.

Age has been discussed by members of the Computer Science department at the University of Victoria as a possible factor in persistence in computer science. Their prediction is that older females and younger males are more likely to persist in computer science. Thus, the path coefficient p94 which relates the effect of age on persistence in computer science has been retained as a non-zero coefficient in both the model for females and the model for males.

The path coefficient p95 represents the effect of the tendency to stereotype computer science on persistence in computer science. In their synthesis of the literature related to mathematics participation, Chipman and Wilson (1985) observe that sex stereotyping of mathematics did not have any significant relationship with the intention to take further mathematics courses. Since parallels in computer science and mathematics participation seem to exist, this path is assumed to have zero-coefficients for both the male and female models.

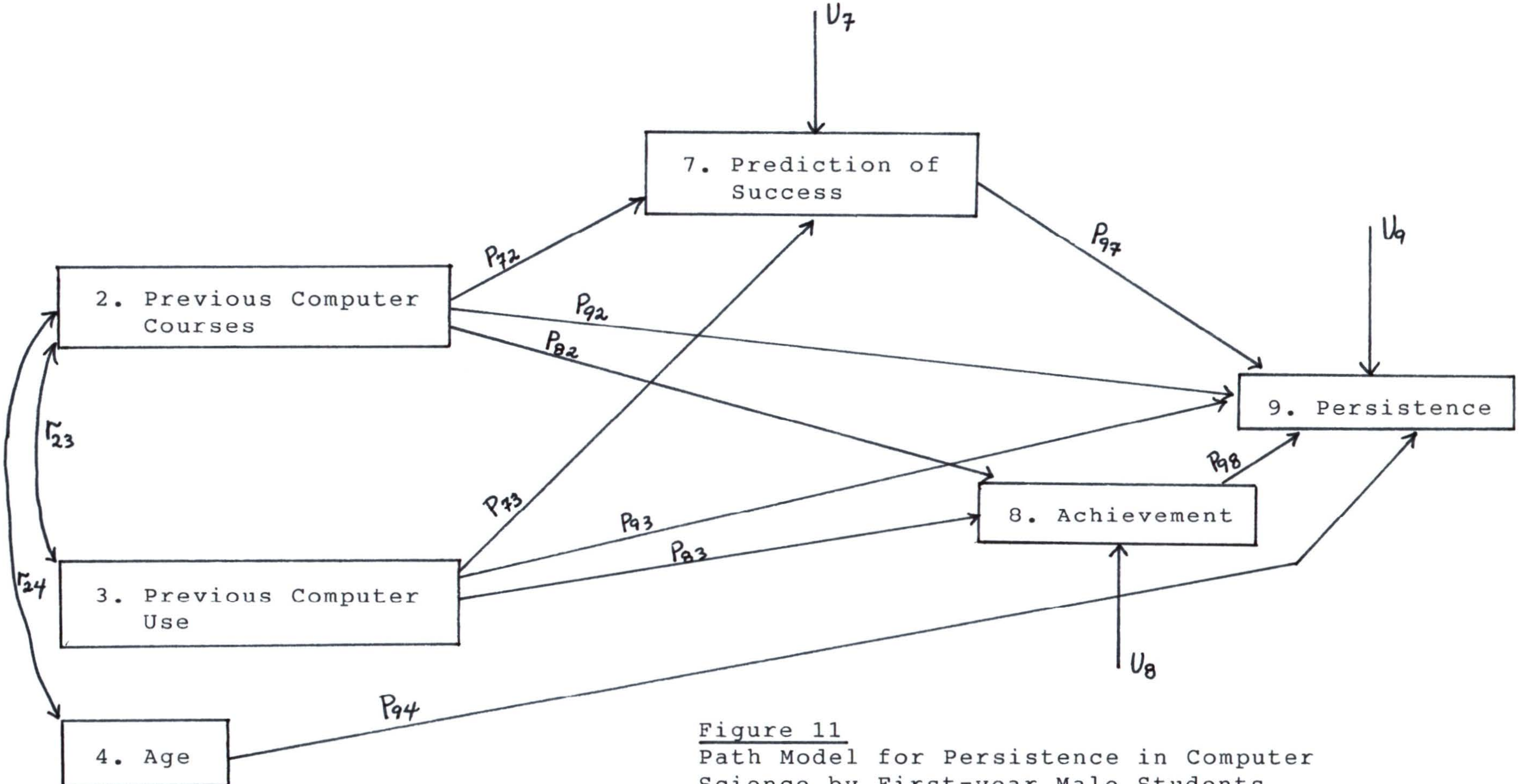
The personal feeling that the student has in a computer science course, his or her comfort level, may have an effect on persistence in computer science. This effect is shown by the path coefficient p96. In their study of undergraduates who pursue science majors, Ware, Steckler, and Leserman (1985) relate that enjoying a science course more than other courses was a predictor for pursuit of a science major for both male and female students. This affective factor seemed to influence the persistence in a science major more for females than for males. Casserly and Rock (1985) report that persistence in advanced placement mathematics courses seems to be more related to environmental factors for females than for males. Hence, this path p96 is retained in the model for females but not in the model for males.

The path coefficient p97 is related to the effect of prediction of success in Computer Science 110 on persistence in computer science courses at the University of Victoria. Casserly and Rock (1985) observed that self-assessment in advanced placement calculus correlated with aspirations in a technical career for males, but not for females. They relate that being in an advanced placement program seems to give males the confidence to plan any career that they want. Both Casserly and Rock (1985) and Ware, Steckler, and Leserman (1985) observe that females are influenced more strongly by their actual achievement in science and mathematics courses and set exceedingly high standards for themselves. Their confidence in the present course does not seem to correlate strongly with further participation. Hence, this path, p97, is retained in the male model, but not in the female model.

The effect of achievement on persistence in computer science is shown by the path coefficient p98. Achievement in first-year university level computer science correlated strongly with persistence in computer science for both males and females (Campbell & McCabe, 1982). Although the fact that grades influence persistence in further courses has been noted by both Casserly and Rock (1985) and Ware, Steckler, and Leserman (1985), there are mixed feelings on whether grades are a more important factor in persistence for males or females. Ware, Steckler, and Leserman (1985) relate that females are influenced more strongly by environmental factors and personal feelings than by grades while males make their decisions about further courses based on grades in freshman courses and prior commitment to their major. Casserly and Rock (1985) observe that males with their greater self-confidence in their ability will pursue further courses despite weaker grades while female students are strongly influenced by grades in the most recent course when they are making decisions on future courses. Thus, this path is considered an integral component of both models with a prediction that the path coefficient will probably be larger for males than for females as the persistence of females seem to be influenced by more environmental and personal variables which the literature relates do not seem to influence the persistence of males.

Development of Parsimonious Models for Females and Males

The goal of path analysis is to develop a parsimonious model by assigning path coefficients of zero to some of the paths in the fully recursive model prior to doing the analysis. The assignment of zero coefficients is based on the review of the literature and knowledge about the area. Figures 11 and 12 are proposed path analytical models which illustrate the anticipated differences that the exogenous and endogenous variables have on the persistence in computer science for males and females. In general, the models predict that males will seem to be affected to a greater extent by the more concrete factors--previous computer science courses, previous computer experience, and grades in Computer Science 110 as well as the self-confidence measure--prediction of success. The model for females hypothesizes the increased influence of the affective variables--attitude to mathematics, comfort level in Computer Science 110, self-confidence in computer science (prediction of success), stereotypes of computer science held--on the persistence of females in computer science as well as the more indirect effect of the concrete variables which are predicted to more directly influence the persistence of males.



<u>Figure 11</u>
Path Model for Persistence in Computer Science by First-year Male Students

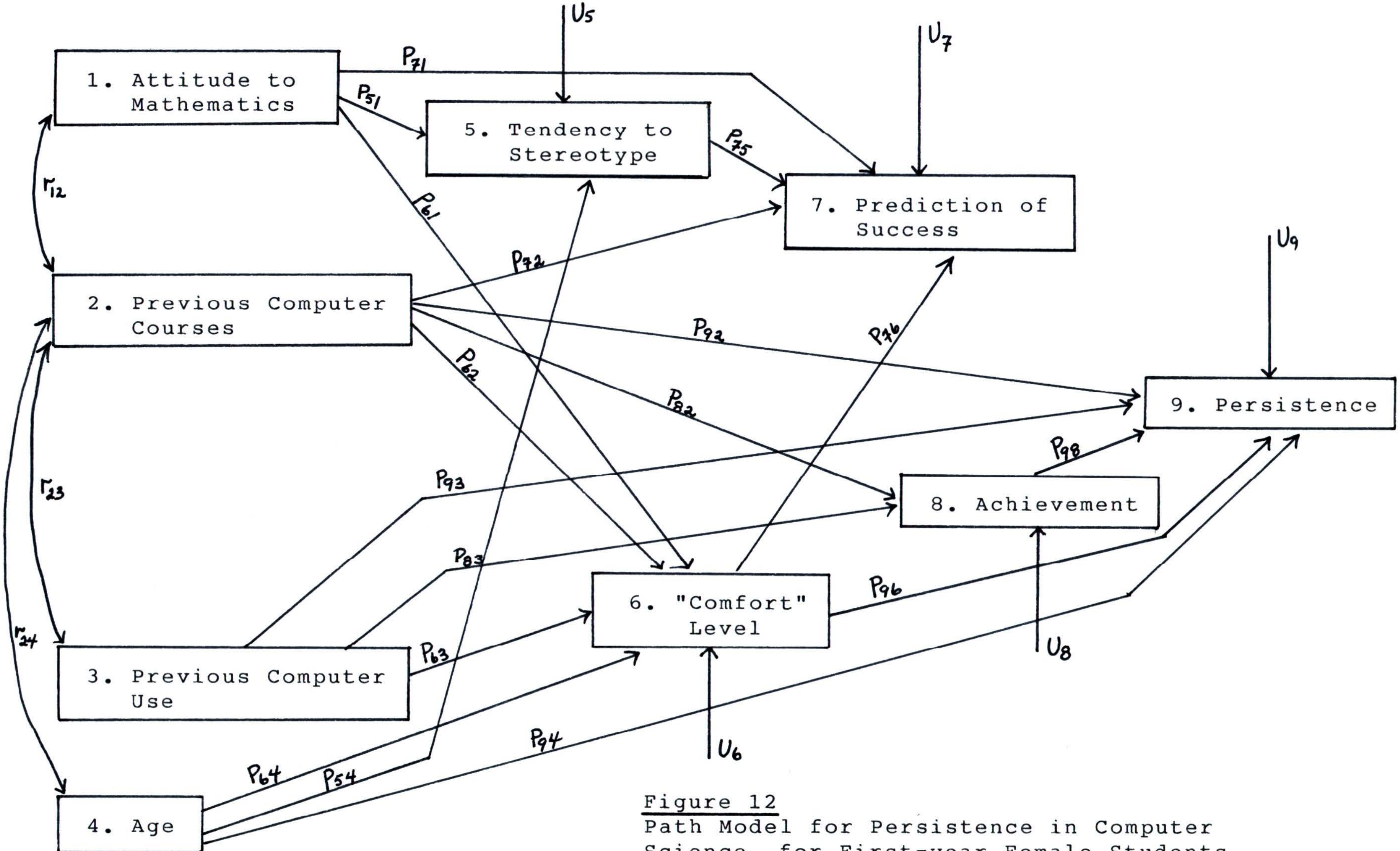


Figure 12
Path Model for Persistence in Computer Science for First-year Female Students

Figure 13 provides another comparison of the male and female models by considering the strengths of certain paths from the fully recursive model. The path strengths from the fully recursive model are used as it is the only model which contains all the paths considered in these comparisons. Plus signs (+) along the paths indicate that these paths are predicted to be stronger for females than for males; equal signs (=) indicate a prediction that coefficients will be approximately equal for the sexes; and minus signs (-) indicate that the path coefficients will be weaker for females than for males.

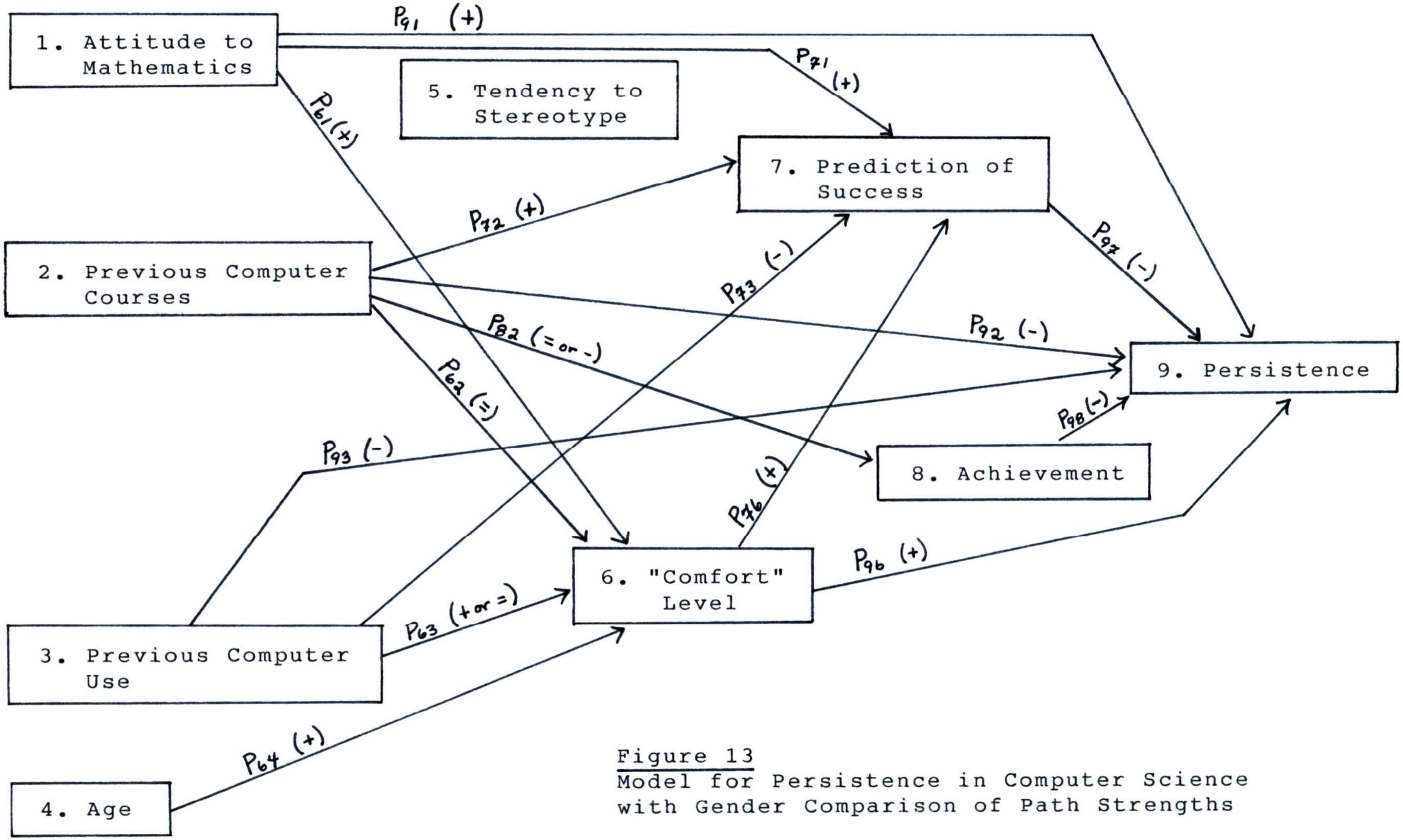


Figure 13
Model for Persistence in Computer Science with Gender Comparison of Path Strengths

CHAPTER 4

Statement of the Problem

The immediate purpose of this study is to better understand the differences in persistence in computer science by male and female students enrolled in the first-year computer science course at the University of Victoria. This is done using the path analytical models developed for males and females based on earlier studies related to gender differences in technical subjects: mathematics, computer science, and the physical sciences. The models is then be tested using responses on the variables in the models by students who were enrolled in Computer Science 110 in September 1986 and who indicated that they intended to persist in the study of computer science during the next semester.

In addition to the causal assumptions considered in the path analytical model, this study considers the following overall hypothesis:

> The models for persistence in computer science for males and females differ. The fit of each model is best for the gender for which it is intended. To test the fit of the models, the female model is tested using the responses of the male sample on the variables in the female model; it is hypothesized that the residuals for males tested on the female model are greater than for females tested on the female model. Likewise, it is

hypothesized that the male model is a better fit for the male subjects than for the female subjects resulting in a larger residual term for the male model when it is tested using the female sample than when it is tested using the male sample.

In addition, the models will be used to focus attention on the following set of secondary hypotheses based on particular components of the overall models:

1. Prediction of success, as a reflection of self-confidence, should be positively related to persistence. The more confident one feels about computer science the more likely one is to continue in it. Female students will be less likely to predict success in computer science than male students and will be more likely to relate other considerations to persistence; therefore, there will be a weaker path coefficient between prediction of success and persistence for female students than for male students.
2. Likewise, personal comfort in the first-year computer science lab and lecture should be positively related to persistence. The relationship is predicted to be stronger for females than for males as females tend to be influenced more by environmental factors.
3. Previous experience in computer use and previous computer courses should be positively related to persistence. This relationship will be stronger for

males than for females because persistence for females will be affected by other variables not as influential for males.

4. Achievement in first-year university-level computer science should also be positively related to persistence in computer science. Because females are assumed to be influenced by a number of other variables, it is further hypothesized that the relationship between achievement and persistence will be greater for males than for females.

5. Attitude towards mathematics will be positively related to persistence in computer science. It is further hypothesized that this relationship will be stronger for female students than for male students because females seem to be more strongly influenced by attitude to mathematics in technical courses than are male students.

6. Age is related to persistence with older women and younger men being predicted more likely to persist than younger women and older men.

The secondary purpose of this study is to suggest appropriate or possible intervention strategies that will facilitate an improvement in persistence rates in computer science courses for first year students both male and female.

CHAPTER 5

Methodology

Subjects

This study involves students registered in the first year computer science course (CSC 110) at the University of Victoria. Of the 373 students registered in the fall 1986 offering of this course, 308 students, 212 males and 96 females, completed a survey of attitudes towards computer science and computer scientists in their computing laboratory sections during the fourth week of the course in September, 1986. These 308 students were all of the students attending laboratory sessions during that week.

At this point in the course the students had completed only two small lab assignments and had not yet been tested. Hence, it is assumed in this study that their attitudes to computer science and mathematics were generally the same as they were when the students entered the course. The students were enrolled in a variety of faculties: 232 (75%) in Arts and Science, 51 (17%) in Engineering, 10 (3%) in Human and Social Development, 7 (2%) in Education, and 8 (3%) in other faculties. Table 2 summarizes the gender and age breakdown of this sample.

Table 2

Gender and Age of Computer Science 110 Students - University of Victoria, September, 1986

	Gender	
Age Range (years)	Male (%)	Female (%)
Under 20 years	60.4	59.4
20 - 23 years	22.2	22.9
24 - 27 years	10.8	6.3
28 - 40 years	4.7	11.5
Over 40 years	1.9	1.0
	N=212	*N*=96

Of the students responding to the survey 90.6% had some previous experience using computers and, in fact, 34.9% related having extensive prior computer experience. Of the students having no previous computer experience, 10.4% were females and 9.0% were male. Of the respondents 55.8% (58% of males, 51% of females) had taken a computer science/ computer studies course in Grade 11; 17.2% of the students (18.9% of males, 13.5% of females) had taken a computer science course in Grade 12.

For the testing of the path analytical model, only those students who had indicated that they would or may be enrolling in a computer science course in the next semester, that is, only those who had intentions of persisting in computer science, were included for analysis. Only 12.7% of the 308 students surveyed indicated that they did not intend to enroll in a computer science course in the next semester. Indeed, 269 students, 189 males and 80 females, anticipated enrolling in further computer science courses. Thus, in the fourth week of September 83% of females and 89% of males felt that they would be enrolling in the subsequent course, either Computer Science 115 or Computer Science 160 depending on their major.

Instrument

Description of the instrument. A 40-item survey questionnaire (Appendix A) was designed to gather information on previous computer experience, demographic information, feelings related to the computer courses and mathematics, and perceptions of the computer science profession and professional. Ten of the questions in the survey instrument are related to demographic information such as age, gender, location of high school, type of high school, and university major. Seven questions relate to prior computer experience at home, work, or through self-study; four questions relate to previous computer courses; four questions relate to feelings of comfort and self-confidence in the university level computer science class; four questions relate to perceived career opportunities in computer science; one question relates to the student's attitude to mathematics; two questions relate to the student's plan to take further computer science courses. The final eight questions deal specifically with personality-related stereotypes which may be associated with computing. These eight questions dealt with the perceived relationship between computer science and mathematics, and perceived characteristics of the computer scientist. The characteristics suggested by these items were mathematical ability, scientific ability, interpersonal and communication skills, and job dedication.

Rationale for items on the instrument. Of the eight items dealing with stereotypes relating to computer use, two items pertain to the perceived relationship between mathematics and computing that is suggested by Hawkins

(1985), Lipkin and McCormick (1986), and Saunders (1979). Two items relate to the perception of a strong association of aptitude in sciences and computing (Hawkins, 1985; Lipkin & McCormick, 1986). Rosenbaum (1986) relates the need for strong interpersonal and communication skills; three items were related to these concepts. Women frequently associate scientists with dedication and and commitment (Deboer, 1985; Erickson, Erickson, & Haggerty, 1980); the final item tested this perception. These eight items with their means and standard deviations are given in Table 3.

Table 3

Survey Items Relating to Sex-role Stereotype of Computer Science with Means and Standard Deviations

Item number	Item	Female Mean	Male Mean
1	How much do you see computer science to be dependent on mathematics?	2.000 (1.06)	1.941 (1.37)
2	To be a good computer scientist one must think scientifically?	2.457 (1.04)	2.662 (.96)
3	To be a good computer scientist one must be mechanically minded?	2.055 (1.04)	2.182 (1.17)
4	To be a good computer scientist one must be good at math?	2.523 (.95)	2.677 (.98)
5	To be a good computer scientist one must be good with people?	2.484 (1.04)	2.383 (1.12)
6	To be a good computer scientist one must be a good communicator?	1.535 (1.04)	1.665 (1.18)
7	To be a good computer scientist one must be sensitive to people's feelings?	2.391 (1.06)	2.366 (1.09)
8	To be a good computer scientist one must be dedicated to one's work?	3.070 (.82)	3.286 (.72)
		N=212	N=96

Note. Standard deviations are given in parentheses below the mean values. Scale: 0 (least stereotyped) to 4 (most stereotyped)

The perceived job potential in technical careers was queried in four items; these items accessed the perceived appropriateness and possibility of computing careers for women and are related to sex-typing computing as a "masculine" activity (Collis, 1985; Hawkins, 1985). In addition to this possible need for gender-appropriateness, self-confidence and a feeling of belonging and security have been related as important factors in achievement in non-traditional courses for women. Three questions related to personal feeling in the classroom pertaining to how supportive the student found the lab situation, how supportive the student found the lecture environment, and their overall feeling of comfort in the course. Bostock, Seifert, and McArdle (1987) related that women did better and dropped out at a lower rate from courses in which they felt personally comfortable and unthreatened. Previous experience in computer use as well as in programming have been investigated as possible factors in achievement in computer science (Greer, 1986). The possible relationship between these factors and persistence necessitated their inclusion in the questionnaire.

Two professionals in the computer field reviewed and supported the appropriateness of the questions in the instrument in terms of both content and readability. The objective form of the instrument would suggest that reliable results would be obtained. It is unlikely that situational variations would affect the consistency of adult subjects responding to this type of short objective survey instrument. Explicit instructions in written form were given to students responding to the survey and the instructors who administered the survey read a standard script to each group. This standardized administration of the survey instrument would add to the support of the reliability of the survey results. Any variation in the results can be considered minimal and random.

Administration Procedure

The survey instrument was administered to the students during their computer science laboratory at the University of Victoria in the fourth week of September, 1986. Trained researchers administered the 40-item survey to the students in the first 20 minutes of each of the 18 Computer Science 110 lab sections. A standardized script, which assured the students that the results of the survey would be anonymous, that only overall trends would be determined from the data, and that their participation in the survey was completely voluntary, was read to each lab section before the students completed the survey. All students attending the labs that week completed the survey. Of the 373 students enrolled in the Fall 1986 Computer Science 110 course, 308 students or 83% of students enrolled completed the survey form.

Development of the Variables for the Path Analysis

Of the nine variables included in the path analytical models, five of the variables-- age, attitude to mathematics, previous computer experience, comfort level in Computer Science 110, and prediction of success in Computer Science 110--involve the response to a single question on the survey questionnaire (See Items 1, 3, 28, 27, 24; Appendix 1). All of these variables were measured on a three- or five-point Likert scale except for age which was answered on a continuous scale of age groupings. The frequencies of responses by gender, means, and standard deviations, where appropriate, are listed in Table 4.

The comfort level variable was related to two other questions in the questionnaire which were included to discern if there was any perceived difference in the classroom atmosphere in the labs and the lectures. Correlations between these three variables and the persistence variable were as follows:

comfort level and lecture atmosphere-- .407 for males, .517 for females;

comfort level and lab atmosphere-- .343 for males, .486 for females;

lecture atmosphere and persistence-- .140 for males, .107 for females;

lab atmosphere and persistence-- .267 for males, .025 for females.

Persistence of females is more strongly related to lecture atmosphere while persistence of males is more strongly related to laboratory atmosphere.

Data for two of the nine variables--achievement in Computer Science 110 and persistence in computer science--were obtained from the records of the Computer Science department. The achievement in Computer Science 110 variable is recorded as the grade received in Computer Science 110 ranging from fail or withdraw (0) to A+ (9). The persistence variable is a categorical variable with students who did not continue into the second semester of computer science receiving a score of zero and those who did register for a follow-up course in computer science receiving a score of 2. Frequencies for these two variables and the means and standard deviation for the achievement variable are given in Table 4.

The variable which relates previous computer science courses is a composite variable formed from the responses to three questions (See Items 8, 9, 10; Appendix 1) on the survey questionnaire. Students received a score of 1 if they had taken a computer science course in either Grade 11 or Grade 12 or had taken Computer Science 100 or a course equivalent to it. Students who had not taken any of these courses or their equivalents received a score of zero. Frequencies for the previous computer science courses variable are given in Table 4.

Table 4

Frequencies, Means, and Standard Deviations for Exogenous and Endogenous Variables in the Path Analytical Model for Persistence in Computer Science

Scale		Gender	
		Male %	Female %
Attitude to Mathematics			
Which of the following best reflects your feelings about mathematics?			
Don't enjoy, do poorly	(0)	3	5
Don't enjoy, do okay	(2)	38	39
Enjoy	(4)	59	56
Mean		3.14	3.03
Standard deviation		1.10	1.19
Previous Computer Experience			
Which of the following best describes your experience with computers?			
No previous experience	(0)	9	11
Games only	(1)	5	9
A few times	(2)	40	65
Extensive	(3)	46	15
Mean		2.23	1.84
Standard deviation		.91	.82
Comfort Level in Computer Science 110			
Based on what you have experienced so far in CSC110, how do you feel in the course personally (not academically)?			
Very uncomfortable	(0)	4	8
Slightly uncomfortable	(1)	24	30
No opinion	(2)	3	9
Comfortable	(3)	48	41
Very comfortable	(4)	20	13
Mean		2.57	2.21
Standard deviation		1.17	1.22
Prediction of Success			
Which of the following best describes your predictions about your achievement in CSC110?			
Concerned will not complete	(0)	1	4
Not very successful but will pass	(1)	5	9
Successful but some concerns	(2)	33	53
Confident of success	(3)	60	29
Mean		2.54	2.13
Standard deviation		.64	.74

(table continues)

Scale	Gender: Male %	Gender: Female %
Age		
Which of the following best describes your age?		
Under 20 years (0)	60	58
20 - 23 years (1)	22	23
24 - 27 years (2)	12	6
28 - 40 years (3)	4	13
More than 40 years (4)	2	1
Achievement in Computer Science 110		
The final grade attained in Computer Science 110 (grade point value):		
0 Fail or withdraw	28	29
1 D	9	4
2 C	5	8
3 C+	9	13
4 B-	9	14
5 B	10	8
6 B+	11	4
7 A-	7	15
8 A	5	5
9 A+	8	3
Mean	3.54	3.39
Standard deviation	3.05	2.84
Previous Computer Courses		
No previous computer course (0)	32	34
Previous computer course(s) (1)	68	66
Factor Scores, Tendency to Stereotype Computer Science		
Mean	.004	.118
Standard deviation	1.000	.963
Persistence in Computer Science		
Did not persist (0)	49	55
Did persist (2)	51	45
	N=189	N=80

The ninth variable included in the path analysis was a variable which related the tendency to stereotype computer science. The values used for this variable were the factor scores which resulted from the factor analysis of eight variables considered to be related to stereotyping computer science in a previous related study (Connors, 1987). These eight variables were listed in Table 3.

In order to interpret the responses to these eight questions more easily, these eight variables were grouped by extraction-method factor analysis with varimax rotation. Three factors with eigenvalues greater than 1.00 were retained. These factors accounted for 61% of the variance. Table 5 summarizes the results of the factor analysis.

Table 5

Results of Extraction Analysis with Varimax Rotation on the Eight Variables Related to Sex-role Stereotyping

	Factor Loadings		
Item	1	2	3
1		.839	
2			.568
3			.648
4		.817	
5	.853		
6	.790		
7	.809		
8			.684
Eigenvalue	2.22	1.56	1.09
Percent of variance	27.7	19.5	13.6

Note. The item numbers correspond to those in Table 3. Only factor loadings greater than .55 are listed.

The first factor was interpreted as a "people skills" factor, as the variables with highest loadings on this factor related to being a good communicator, being sensitive to people's feelings, and being good with people. The second factor related strongly to the perceived association between skill in mathematics and proficiency in computer science. This second factor was, therefore, interpreted as a "math" factor. The third factor was related to attitudes towards one's vocation as a scientist and was interpreted as a "science" factor. The variables related to thinking mechanically, thinking scientifically, and being dedicated to one's work loaded heavily on this "science" factor.

Factor scores were calculated for each subject on these three factors and were used in a subsequent series of multivariate analyses of variance to examine the differences in the perceived stereotyping of computer science by the various student groups and the computer professionals. The people skills factor was the factor on which most of the student groups differed significantly; thus, the factor scores from this factor are used as a measure of tendency to stereotype in the path analysis. The factor scores are interval scores with the larger scores indicating a greater tendency to stereotype computer science. Means and standard deviations for the people-skills factor scores were given in Table 4.

The correlations between the nine variables included in the path analysis are listed in Table 6 for both males and females. Multiple regression equations for each of the endogenous variables included in the various models were also calculated for use in the path analysis procedure.

Table 6

Correlations for the Variables in the Path Analysis Models

Males[a]

Variables	1	2	3	4	5	6	7	8	9
1 Attitude to mathematics	-								
2 Previous computer courses	.012	-							
3 Previous computer experience	.165	.590	-						
4 Age	.051	-.225	-.152	-					
5 Tendency to stereotype	-.106	.029	-.050	-.148	-				
6 Comfort level	.026	.198	.269	-.111	-.171	-			
7 Prediction of success	.106	.133	.353	-.056	-.100	.420	-		
8 Achievement	.123	.073	.292	-.175	-.058	.272	.339	-	
9 Persistence	.202	.132	.316	-.256	-.025	.242	.345	.702	-

(table continues)

Females[b]

Variables	1	2	3	4	5	6	7	8	9
1 Attitude to mathematics	-								
2 Previous computer courses	-.052	-							
3 Previous computer experience	.017	.508	-						
4 Age	-.053	-.340	-.125	-					
5 Tendency to stereotype	-.128	-.036	-.122	-.152	-				
6 Comfort level	.319	.300	.340	-.256	.005	-			
7 Prediction of success	.301	.284	.315	-.145	-.123	.546	-		
8 Achievement	.233	-.052	.098	.036	-.051	.275	.152	-	
9 Persistence	.236	.008	.181	-.250	-.069	.339	.225	.489	-

Note. a *N*= 189. b *N*= 80.

CHAPTER 6

Results

The standardized betas and the multiple R-squares which resulted from the series of multiple regression equations for the endogeous variables are shown in Table 7. These beta coefficients and the appropriate correlations from Table 6 were substituted into the computer program developed by Fox (1980) for calculating path coefficients. The multiple R-squares from these regression equations were also used to calculate the percent of variance not accounted for by the models and the percent of joint variance accounted for by the models; these percentages are shown in Table 8.

Table 7

Standardized Betas and Multiple R- squared for the Regression Equations on the Endogenous Variables in the Path Models

Endogenous Variable	Variables 1	2	3	4	5	6	7	8	R^2
				Fully Recursive Model: Female Data					
5 Tendency to stereotype	-.128	-.043	-.147	-.195					.066
6 Comfort level	.285	.073	.283	-.196	.054				.266
7 Prediction of success	.173	.166	.052	.061	-.082	.449			.362
8 Achievement	.142	-.156	.166	.099	-.001	.274	-.034		.143
9 Persistence	.065	-.165	.122	-.304	-.077	.088	.045	.440	.390
				Hypothesized Model for Females					
5 Tendency to stereotype	-.128			-.156					.037
6 Comfort level	.278	.071	.275	-.207					.264
7 Prediction of success	.170	.172			-.099	.449			.357
8 Achievement		-.194	.265						.051
9 Persistence		-.170	.139	-.292		.128		.451	.376
				Females tested on Male Model					
5 Tendency to stereotype									
6 Comfort level									
7 Prediction of success		.159	.228						.117
8 Achievement		-.194	.265						.051
9 Persistence		-.180	.149	-.317			.112	.469	.375

(table continues)

Endogenous Variable	Variables								R^2
	1	2	3	4	5	6	7	8	
Fully Recursive Model: Male Data									
5 Tendency to stereotype	-.085	.029	-.066	-.146					.033
6 Comfort level	-.020	.041	.244	-.070	-.178				.114
7 Prediction of success	.039	-.114	.325	-.017	-.025	.357			.260
8 Achievement	.060	-.148	.210	-.159	-.006	.138	.213		.196
9 Persistence	.115	.000	.058	-.125	.017	-.009	.108	.614	.538
Hypothesized Model for Males									
5 Tendency to stereotype									
6 Comfort level									
7 Prediction of success		-.101	.407	-.020					.131
8 Achievement		-.158	.249	-.165			.262		.180
9 Persistence		-.016	.082	-.122			.105	.621	.527
Males tested on Female Model									
5 Tendency to stereotype	-.094			-.141					.030
6 Comfort level	-.005	.036	.255	-.044					.083
7 Prediction of success	.088	.053			-.025	.413			.196
8 Achievement		-.143	.358						.088
9 Persistence		-.023	.112	-.119		.020		.643	.516

Table 8

Variance in the Path Analytical Models

Endogenous Variable	Model					
	Fully Recursive		Hypothesized		Test on Opposite Model[a]	
	Female	Male	Female	Male	Female	Male
	Total Variance Not Accounted For					
Stereotype	.934	.967	.963	-	-	.970
Comfort Level	.734	.886	.736	-	-	.917
Prediction of Success	.638	.740	.643	.869	.883	.804
Achievement	.857	.804	.949	.907	.949	.912
Persistence	.610	.462	.624	.473	.625	.484
	Joint Variance Accounted For					
Full Model	.771	.765	.730	.627	.476	.684

Note. a Female denotes females being tested on the male model; male denotes males being tested on the female model.

<u>The Female Model</u>

Figure 14 presents the path coefficients and residual terms which resulted from the path analysis procedure for the model developed for female students in Computer Science 110. The path coefficients for the persistence model for the female students registered in Computer Science 110 indicate the following equations:

Tendency to Stereotype = -.128*Attitude to Mathematics
- .156*Age + .981

Comfort level = .278*Attitude to Mathematics + .275*Previous Computer Use + .071*Previous Computer Courses
- .207 Age + .858

Prediction of Success = .449*Comfort Level + .307*Attitude to Mathematics + .204*Previous Computer Courses
- .099*Tendency to Stereotype + .802

Achievement = .265*Previous Computer Use - .194*Previous Computer Courses + .974

Persistence = .451*Achievement + .394* Previous Computer Use + .128* Comfort Level -.318*Age
- .248*Previous Computer Courses + .790

The persistence equation indicates that if the achievement level increases by 1 standard deviation persistence will increase by .451 standard deviations or if age increases by 1 standard deviation persistence will

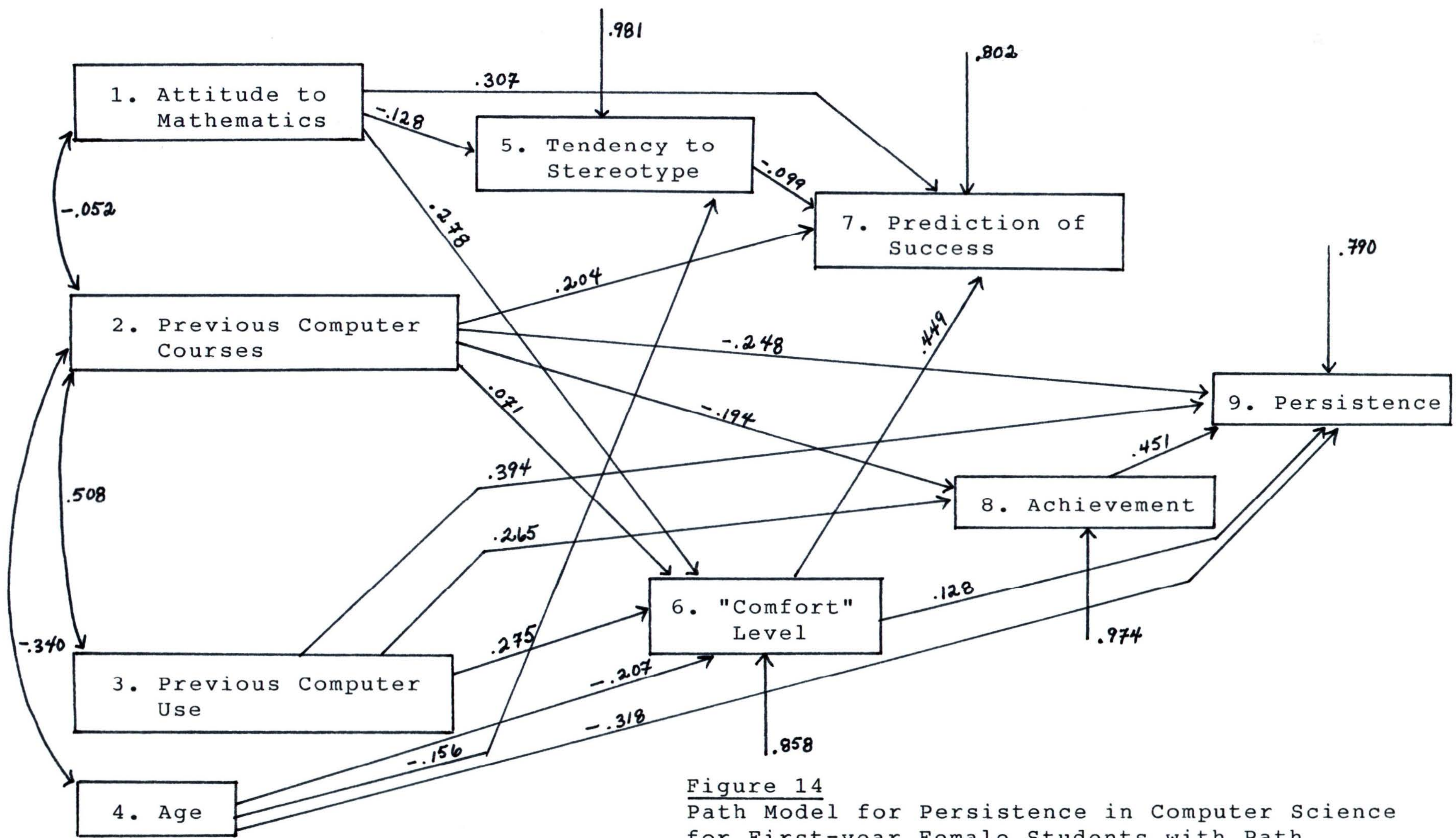


Figure 14
Path Model for Persistence in Computer Science for First-year Female Students with Path Coefficients and Residuals

decrease by .318 standard deviations. Thus, the equation indicates a positive relationship between persistence and achievement, previous computer experience, and comfort level and a negative relationship between persistence and age and previous computer courses. Using Specht's test for the significance of the model from zero, W equals 94.3 which is a significant chi-square, $p < .01$. Thus, the 73% of the joint variation of the dependent variables explained by the model is significantly different from zero.

While the model accounts for 73% of the joint variance in the variables, the fully recursive model with all possible paths accounts for only 77% of the joint variance. The Q statistic for the goodness of fit of the model for females compared with the fully recursive model for females is .847; the residual term for persistence is .790. The squared residual term indicates that the female model accounts for approximately 38% of the total variance in persistence of females in computer science; however, this fit is very good when one considers that the fully recursive model which includes all 8 dependent variables in its equation for persistence accounts for only 39% of the total variance in persistence. Hence, the variables not included in the persistence model for females--attitude to mathematics, tendency to stereotype computer use or users, and prediction of success--were not important variables for the persistence of females when the other variables were retained. Thus, the female model has a very good overall fit for persistence of females in first-year computer science.

During the path analysis of the female model indirect effects for several paths which had not been included in the model appeared. Two indirect path coefficients, one for previous computer use (.123) and one for age (-.077) resulted for the endogenous variable, prediction of success. An indirect effect also arose for attitude to mathematics (.036) in the persistence equation.

The Male Model

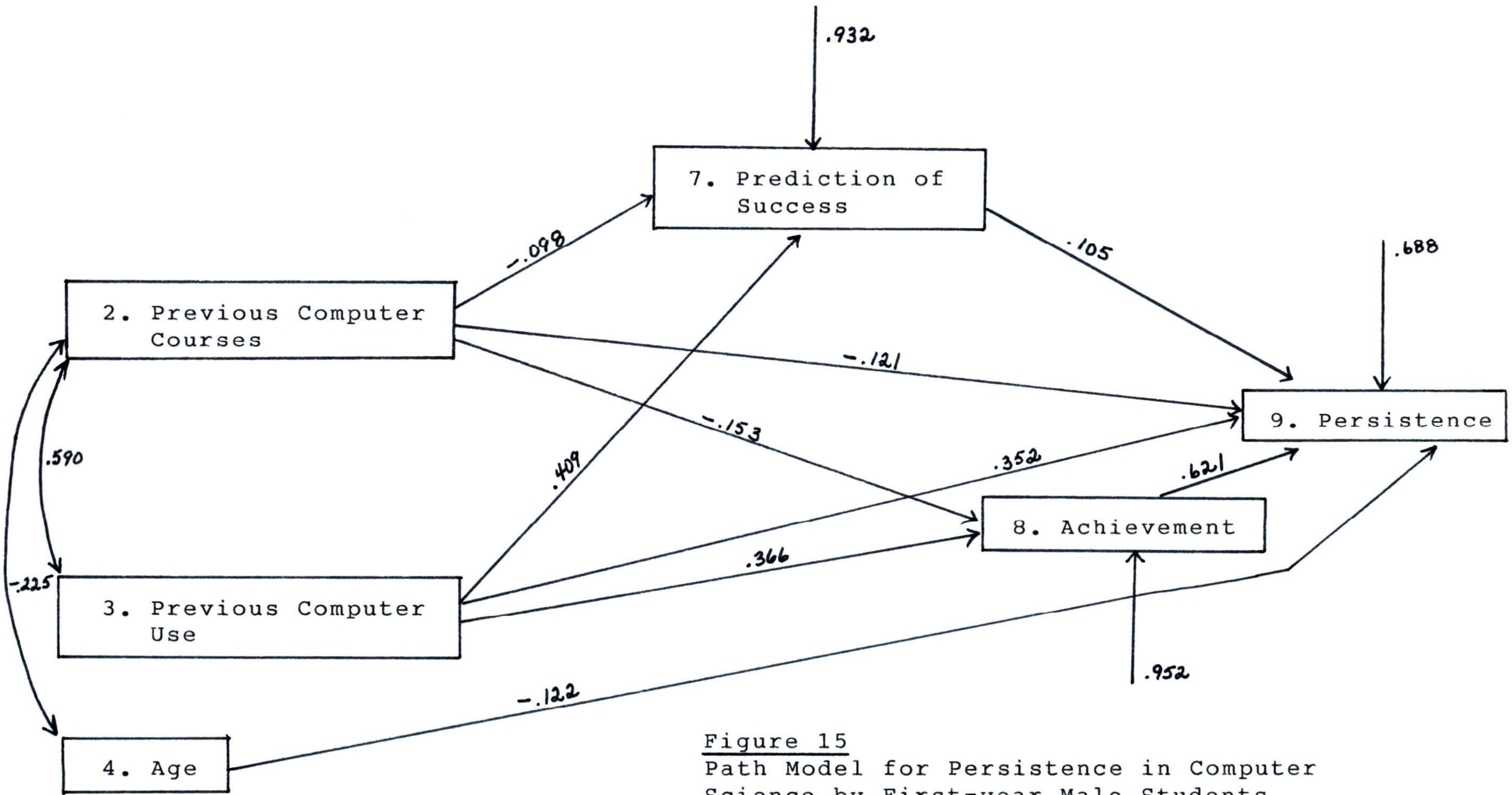
Figure 15 presents the path coefficients and residual terms which resulted from the path analysis procedure for the model developed for male students in Computer Science 110. The path coefficients for the persistence model for the male students registered in Computer Science 110 indicate the following equations:

Prediction of Success = .409*Previous Computer Use
- .098*Previous Computer Courses + .932

Achievement = .366*Previous Computer Use - .153*Previous Computer Courses + .952

Persistence = .621*Achievement + .352* Previous Computer Use + .105*Prediction of Success - .122*Age - .121*Previous Computer Courses + .688

Using Specht's test for the significance of the model from zero, W equals 168.7 which is a significant chi-square,



<u>Figure 15</u>
Path Model for Persistence in Computer Science by First-year Male Students with Path Coefficients and Residuals

$p < .01$. Therefore, the 62.7% of the joint variation of the dependent variables explained by the model is significantly different from zero.

The Q statistic for the goodness of fit of the model for males compared with the fully recursive model for males is .631; the residual term for persistence is .688. The squared residual term indicates that the model for males accounts for approximately 53% of the variance in persistence while the fully recursive model for males accounts for only 54%; thus, the male model for persistence is indeed a very good fit for the data because elimination of all the affective variables--attitude to mathematics, tendency to stereotype computer users and use, and comfort level--reduces the total variance accounted for in persistence by only 1%. However, although the fit of the hypothesized model for persistence in males is very good when compared to the fit of the male data for the persistence variable in the overall model, the fit of the overall model itself is not as good for males as it was for females. The fully recursive model accounts for 76.5% of the joint variance in the male data while the male model accounts for only 62.7% of this joint variance. Thus, while there is a good fit for persistence, the male model is generally not an exceptionally good fit for the overall model.

Testing the Male Model for Females

Figure 16 summarizes the fit of the male model for female students enrolled in Computer Science 110. The path coefficients and residuals for the model when it was tested on the males are given in parentheses. The Q goodness-of-fit statistic for females tested on the male model is .437; the Q statistic for males tested on the male model is .631. The male model tested for females has a joint variance-accounted -for of 47.6% while this model had a joint variance-accounted-for of 62.7% for males. Thus, the male model is a much better fit for males than for females in this sample of Computer Science 110 students.

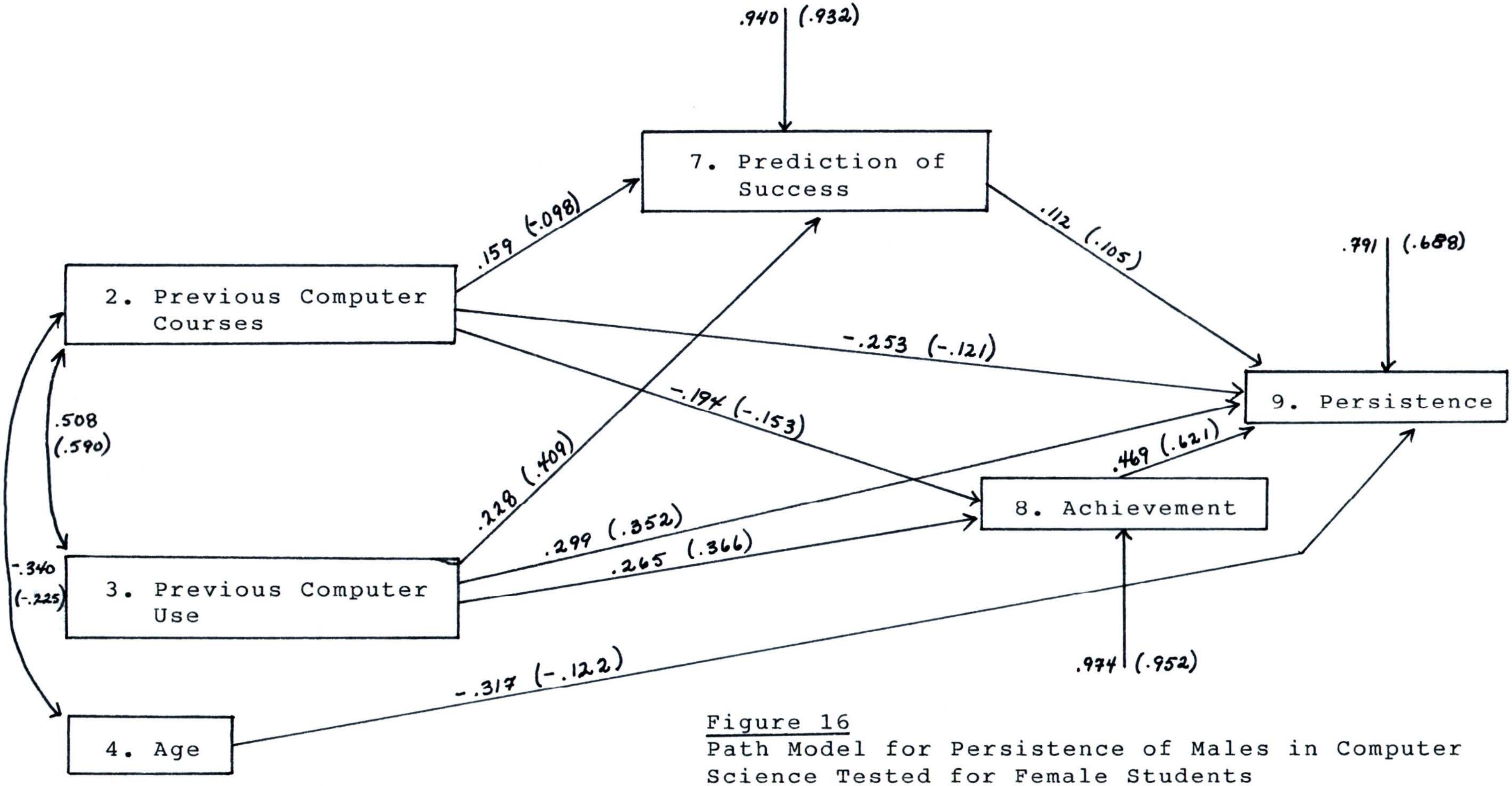


Figure 16
Path Model for Persistence of Males in Computer Science Tested for Female Students

Note. Path coefficients and residuals for males in parentheses.

Testing the Female Model for Males

Figure 17 presents the path coefficients and residual terms when the female model was tested for male students. The path coefficients in parentheses are the coefficients for the model when tested with females. The Q goodness-of-fit statistic for males tested on the female model is .746 as compared to .847 for females tested on the female model. The female model tested for females accounts for 73.0% of the joint variance in the model. When the female model is tested using the male students it accounts for 68.4% of the joint variation in the model. Thus, it seems that the female model with the included affective variables is a better fit for females in this sample of Computer Science 110 students than it is for males in this sample.

As in the path analysis calculations for the female model when the female model was tested for the male sample indirect effects arose for some paths which had not been included in the hypothesized model for females. Similar to the test of the model for females indirect effects for previous computer experience (.105) and age (-.015) on prediction of success resulted for the male sample. Unlike the female sample no indirect effect for attitude to mathematics on persistence arose for the male sample when tested on the female model.

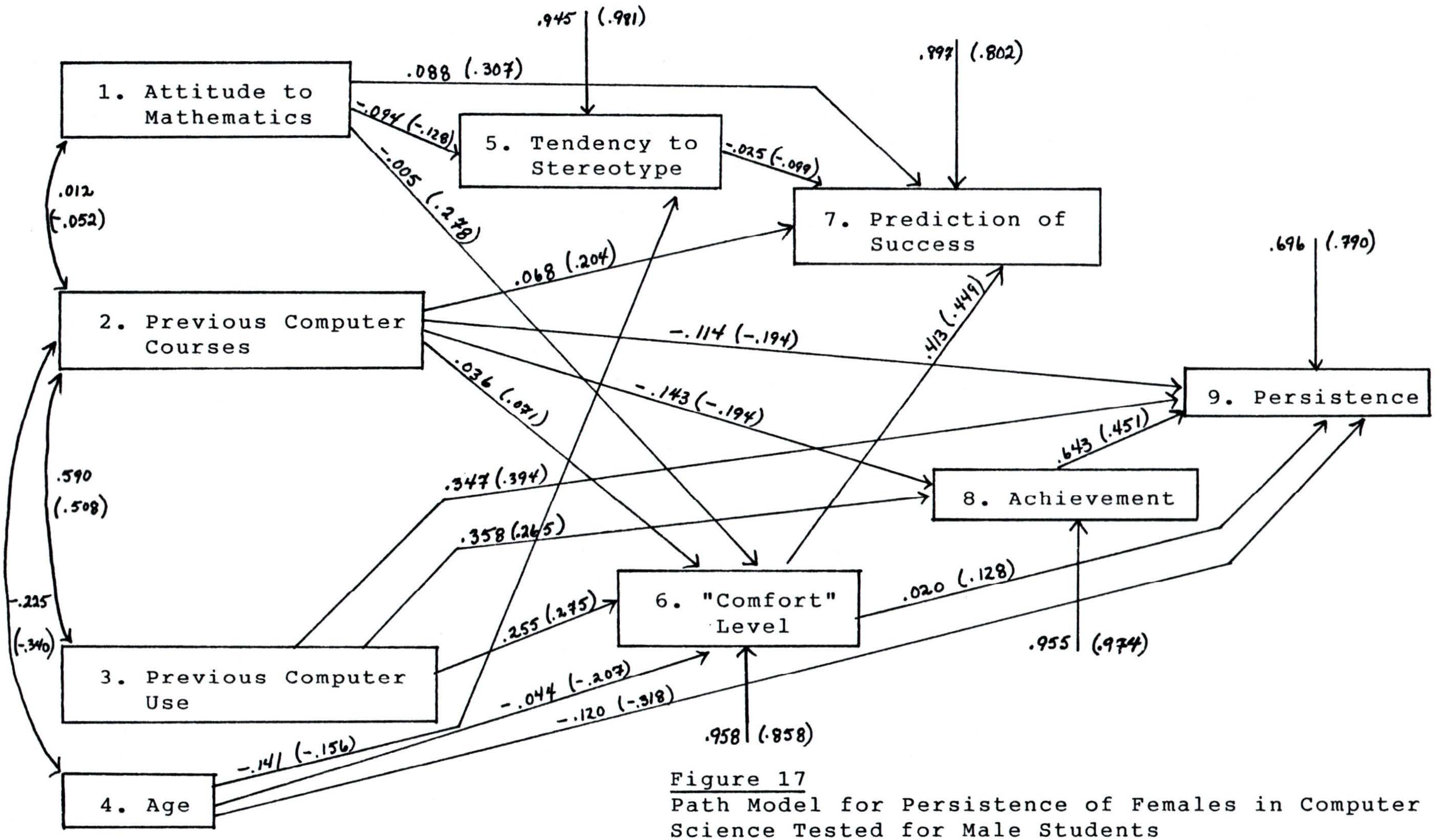


Figure 17
Path Model for Persistence of Females in Computer Science Tested for Male Students

Note. Path coefficients and residuals for females in parentheses.

Testing the Secondary Hypotheses Using the Fully Recursive Model

Figure 18 summarizes the comparison of various paths in the model for which secondary hypotheses were being tested. This figure reflects Figure 13 which indicated the predicted comparisons for the strengths of the path coefficients. Because path coefficients are model-specific, comparisons can not be made from one model to another. Hence, the path strengths for these comparisons were taken from the test of the fully recursive model as it was the only model which contained all the comparisons included in the secondary hypotheses. The path coefficients in the fully recursive model were calculated using the same method as was used for calculating path coefficients in the hypothesized models. The path coefficients for all models are summarized in Appendix B.

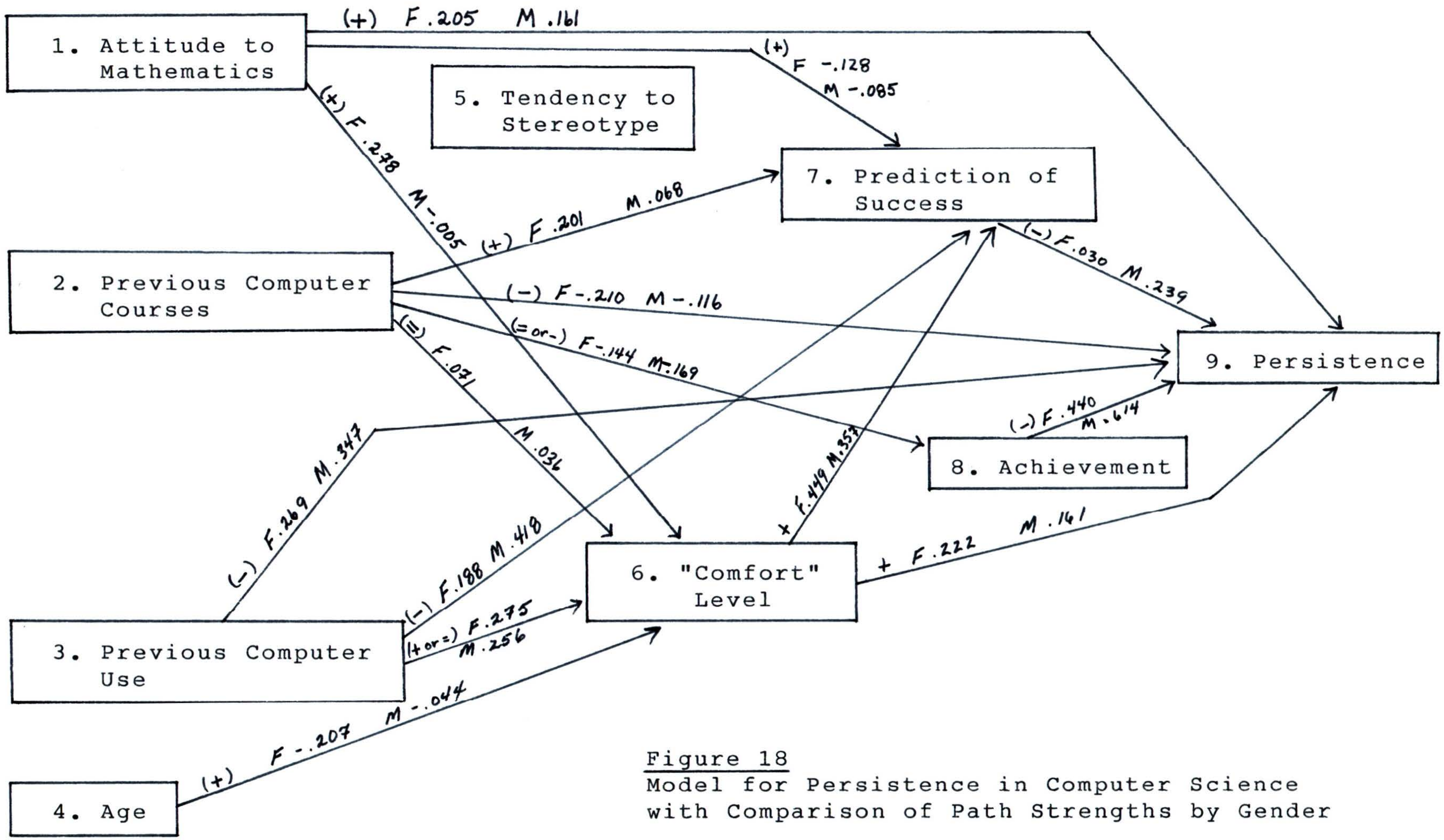


Figure 18
Model for Persistence in Computer Science with Comparison of Path Strengths by Gender

Note. "+" in parentheses indicates that path was predicted to be more positive for females; "-" in parentheses indicates that path was predicted to be more positive for males.

A test for the significance of the difference between two independent correlations was used to test the significance of the differences between pairs of path coefficients relating each of the secondary hypotheses. The first hypothesis predicted that the path coefficient for the effect of prediction of success on persistence would be stronger for males than females. The data showed a stronger but not significantly stronger path coefficient for males than for females. In the other comparisons involving prediction of success which were predicted in Figure 13, the prediction that attitude to mathematics would be more strongly related to prediction of success for females than for males was not supported by the data. In fact, there was a fairly strong negative path coefficient for this variable for females and a weaker negative coefficient for males. As predicted, previous computer courses were more positively related to prediction of success for females than for males. However, previous computer experience had a significantly greater effect on the prediction of success in Computer Science 110 for males than for females ($p < .03$). This relationship supported the predictions in the model. Comfort level in Computer Science 110 was slightly more positively related to prediction of success for females than for males; however, the difference was not significant as had been predicted.

The second hypothesis predicted that comfort level in Computer Science 110 would be more positively related to persistence for females than for males. The data did not support this hypothesis with a significant difference although the path coefficient for females was slightly larger. As predicted in Figure 13 previous computer courses had approximately the same effect on comfort level for male and female students. It had been predicted that age would have a more positive relationship for females than for males; however, the data revealed that age is a suppressor variable for both males and females, albeit stronger for females than males. However, attitude to mathematics was a significantly more important factor in the comfort level of females than for males, $\underline{p}<.016$, as had been predicted.

In the third hypothesis it was predicted that previous computer experience and previous computer courses would be more positively related to persistence for males than for females; the data supported this trend although the differences were not significant. However, previous computer use and persistence had a positive path coefficient while that of the effect of previous computer courses on persistence was negative.

Attitude to mathematics was positively related to persistence as had been predicted. The effect of age on persistence was negative which would indicate that younger students of both sexes were more likely to persist; this did not support the hypothesis that older women would be more likely to persist than younger women.

Previous computer courses had approximately the same, albeit negative, effect on achievement for males and females as had been predicted. However, in accordance with the hypothesis, a significant difference existed for the effect of achievement on persistence ($p < .04$) with achievement being a significantly more important factor in the persistence of males than females.

CHAPTER 7

Discussion

Based on the path analysis models for persistence in computer science, it was found that the persistence process differs for males and females. Although the variables included in this model by no means exhaust the possible experiential and environmental differences which may affect persistence in computer science by males and females, the interactions found between gender and the included variables indicate that the process of persistence in computer science varies by gender, and may involve factors not considered by previous researchers. The following discussion summarizes the conclusions for the various models and relates the apparent differences in the process of persistence and achievement in computer science found in the present study.

The Female Model

The overall fit of the female model when tested with the females registered in Fall 1986 session of Computer Science 110 was relatively good. However, with respect to particular variables, the fit of the model was stronger for some than for others.

Persistence. The fit of the female model with the data is fairly good for persistence as the absolute change in the residual from the fully recursive model to the hypothesized model is very small. However, since the hypothesized model and the fully recursive models only account for 38% and 39% of the total variance in persistence, respectively, it seems that there are factors outside the model which may be important in the persistence of female students in computer science. Campbell and McCabe (1982) and Peterson and Howe (1979) have indicated that mathematics aptitude and ability may be very important factors in the persistence of women in computer science. In the female model for persistence, achievement in the Computer Science 110 course and previous computer experience seem to be the most important factors relating to persistence while previous computer courses has a fairly strong negative path coefficient. This would seem to indicate that for females it is important that they become computer literate to the extent that they have used a computer extensively, but it would seem that it is not necessary or possibly even desirable that this experience should be gained through computer science courses. In fact, the negative path coefficient would seem to indicate that enrolment in the prior computer science courses included in the questionnaire actually had a negative effect on the persistence of these females and as such, in their present states could possibly be detrimental to the persistence of female students in computer science. Comfort level has a positive influence on the persistence of these female students in computer science; there is an indirect effect on persistence from attitude to mathematics although this variable is not directly included in the persistence model. These relationships would seem to support the predicted influence of environmental and personal feelings on the persistence of females in computer science as had been observed by Ware, Steckler, and Leserman (1985) for female science majors.

Achievement. The fit of the female model for achievement in Computer Science 110 is very weak when tested for these female students. The residual .974 shows that previous computer courses and previous computer experience account for only about 5% of the total variance in the grade attained in Computer Science 110. This is a drop of approximately 9% from the fully recursive model. As in the persistence model, previous computer experience is a more important factor than previous computer courses for these female students. In fact, previous computer courses has a negative path coefficient in this model which would seem to indicate that high school computer science courses, as presently given, are not a positive factor in either the achievement level in introductory computer science courses of female students or in the persistence of these students in computer science. Other factors such as attitude to mathematics and comfort level in the class which were not included in the model for achievement may indeed be factors in achievement as indicated by the change in residual from the fully recursive model to the hypothesized model and thus would seem to warrant further investigation. However, the residual for the fully recursive model would seem to indicate that factors outside the model are more important for achievement than those included in this study. Campbell and McCabe's (1982) study would suggest the inclusion of high school grades in mathematics and science courses as well as those variables related to high school computer courses.

Prediction of success. The prediction of success model fit very well for the subjects tested; the change of the residual from .799 (fully recursive) to .802 (hypothesized model) indicates a good fit for the model. Attitude to mathematics and comfort level in the course were major factors in this self-confidence variable; this, in fact, supports the observations of Armstrong and Price (1982), Thomas (1986) and Casserly and Rock (1985) that positive attitudes and feelings are important factors in the self-assessment of female students in technical courses. Interestingly enough, previous computer courses were positively related to prediction of success in computer science; this parallels the findings of Casserly and Rock (1985) in their mathematics study. A positive indirect effect for previous computer experience exists although this path was not included in the model for prediction of success. This would seem to indicate that prior experience may indeed be an important factor for the self-assessment and self-confidence of females in computer science and as such should be investigated further.

Comfort level. Like the model for prediction of success, there is little change from the residual .857 for the fully recursive model to the residual .858 for the hypothesized model. Thus, the model is a good fit for the females tested although it does not account for a large percentage of variance in the comfort level. The perceived relationship between mathematics and computing noted by Hawkins (1985), Lipkin and McCormick (1986) and Lockheed (1985) indeed seems to be a factor in the comfort level of female students in the computer science classroom. Having previous computer experience has a strong relationship to comfort level while having taken previous computer courses seems to have a weaker influence on the comfort level of females. This weaker relationship would seem to agree with the conclusions of Wilder, Mackie and Cooper (1985) that having taken previous computer science courses does not always put females at ease in the introductory university-level computer science course.

Tendency to stereotype computer science. The hypothesized model for tendency to stereotype accounts for less than 4% of the total variance in tendency to stereotype computer science and computer science users. It would seem that the model does not contain variables which strongly influence the sex-typing of computer science. Thus, further study on what factors do indeed affect stereotype of computer science is warranted.

Age. Age is an exogenous variable, but one which some members of the computer science department were interested in for females. Age was negatively related to all the variables in the hypothesized model. Thus, it would seem that as age increases, persistence decreases, prediction of success decreases, comfort level decreases and the tendency to stereotype decreases. However, since 60% of the female subjects were under twenty, these relationships are based on a very small number of older female students and as such require further investigation.

The Male Model

The overall fit of the male model is not as good as that of the female model. Like the female model, it is a better fit for some endogenous variables than it is for others.

Persistence. The hypothesized model for persistence is a good fit for this group of male students. About 53% of the total variance in persistence is accounted for by the model. There is only a small change in the residual term from .680 on the fully recursive to .688 on the hypothesized model. Achievement in Computer Science 110 is the strongest factor in persistence of males in computer science as it was for females; however, the strength of the path coefficient on the fully recursive model indicates that achievement is a significantly more important factor in the persistence of males than it is for females as was predicted in the model. Previous computer experience also has a strong positive relationship for the persistence of males in computer science. As for females, previous computer science courses were negatively related to persistence in computer science for males. Thus, it seems that prior computer experience is an important factor in persistence, but this experience need not be the programming experience which presently seems to be emphasized in high school computer courses.

Achievement. The model for achievement in Computer Science 110 does not fit well when tested with this group of male students. It accounts for only about 9% of the total variance in achievement; likewise, there was a considerable change from the residual, .897 in the fully recursive model to the residual for the hypothesized model, .952. As in the persistence model, prior computer experience related positively to achievement while previous computer courses related negatively. Thus, it seems important for male students to have some computer experience before entering university-level computer science, but this experience could seemingly be gained in other classes, the home, or a work situation instead of in a computer science classroom. However, achievement in introductory computer science would seem to be much more dependent on variables not included in this study. Mathematics and science achievement at the high school-level have been indicated by Peterson & Howe (1979) and Campbell & McCabe (1982) as possibly important factors.

Prediction of success. The hypothesized model for prediction of success shows no change in the residual in the fully recursive model which means for the variables in this model it is a good fit. However, these particular variables only account for about 13% of the total variance in prediction of success. It may well be that factors outside the model such as achievement in high school mathematics and science which have been indicated as factors in achievement in computer science at this level by Peterson & Howe (1979) and Campbell & McCabe (1982) may influence self-assessment by males more strongly than did those included in the model.

Comparison of the fit of the models by gender

When the hypothesized model for males was tested for fit by the female subjects, a smaller Q statistic resulted and all the residual terms are larger for females than for males. Thus, it would seem that the male model is a better fit for males than for females. The major difference in the fit of the male model by females seemed to be the result of the decreased path strength for achievement on persistence as well as the more negative relationships for age and previous computer experience. Most of the relationships in the male model stay the same for both male and female subjects. However, in the relationship for prediction of success the path coefficient for previous computer courses is negative for males but positive for females. This difference in strength would seem to relate that previous computer courses may increase the self-confidence of females while having little effect on self-confidence of males. However, the strength for the relationship of previous computer experience and prediction of success is greater for both males and females than the relationship for previous computer courses. Thus it would seem that while previous computer experience is important for both males and females, actual computer science courses may increase prediction of success for females, but this may not be of sufficient importance to outweigh the seemingly negative relationship that exists between previous computer courses and both achievement and persistence in computer science.

When the hypothesized model for females was tested for the male students enrolled in Computer Science 110, the Q statistic for males was .731 as compared to .847; thus, it would seem that the female model is indeed a better fit for females than it was for males. The residuals for all the endogenous variables except persistence were lower for females than for males. The residual for persistence was lower for males; this would seem to be the result of the much stronger relationship between achievement in Computer Science 110 and persistence in computer science for males. Thus, the female model would seem to fit females better than males in this sample.

The discriminant validity of the path analytical models was supported by this comparison of the models. The model for females had a better fit for females than for males while the male model had a better fit for males than for females. The level of discrimination between the model varied for the various endogenous variables, but the overall discrimination was excellent.

Comparison of paths in the models

As predicted, the persistence of females seemed to be influenced more strongly by environmental or affective variables than was the persistence of males. Of the variables included in the model, achievement in Computer Science 110 and previous computer experience seem to influence persistence most strongly for males and females, and males seem to place greater importance on previous computer experience and their present course work than do females when they make their decisions to continue in their computer science studies. Both comfort level and attitude to mathematics have a stronger relationship with persistence for females than for males. Prediction of success, the self-confidence measure, has a much stronger relationship with persistence for males than for females. As was indicated by Casserly and Rock (1982) self-confidence early in a course seems to be a factor in the persistence of males; females, however, seem to be influenced very little by self-confidence when they make their decisions to remain in a course. It would seem that the feelings that females have towards the computer science class itself and their attitudes to mathematics and computer science are much more important to their decision to continue in computer science than is prediction of success. Although age was considered to be a possible factor by the Computer Science department, there was not a significant difference in the path coefficients relating to age for males and females. An increase in age would result in a decrease in persistence for both males and females. However, this group of female students was very young overall, and the small number of older female students may not result in a clear picture of persistence by age. Further study should be done over time with older students to determine what factors do affect their persistence in computer science.

Although the age of students can not be influenced by changes in the computer science courses, the learning environment and curriculum could possibly be made more appropriate for more mature students, indeed all students, resulting in an increase in persistence. It would seem important to consider intervention strategies which would influence the other variables contained in these models in the classroom situation. Interventions of two types would seem to be required: those which affect the student while he or she is still in high school, and those which can be put in place at the university to affect the learning situation at the level of Computer Science 110.

CHAPTER 8

Implications

Future Theory Building

The causal models developed in this study are by no means the definitive models for the process of persistence in computer science. Other equally plausible models have been and will be used to explain why male and females differ in both achievement in introductory computer science courses at the university level and in persistence in computer science courses. Future research studies should investigate the difference between prior computer experience and previous computer courses as this difference was significant in both the model for males and that for females. The basis of this difference should be investigated to ensure that the differences in this study are real and not simply a result of how the questions were asked. Likewise, it is important to determine how this prior experience differs from the experience gained in the present high school computer science classroom.

In their studies involving persistence in computer science Campbell and McCabe (1982) included several academic factors such as SAT scores for mathematics and English, but did not include any of the affective factors which appear to influence the persistence of female computer science students. In the present study data on high school performance in mathematics, English, science, and computer science courses was not available; future studies should combine these academic factors with the affective environmental factors to ascertain if such a combination would indeed give a more complete model of persistence in computer science.

Since only about one-third of the students enrolled in Computer Science 110 in September 1986 were female and since only 45% of those who intended to enrol in a second computer science course actually did persist, a longitudinal study of persistence and achievement in higher level computer science courses should be carried out to reveal whether the same factors affect persistence of females in subsequent courses. It may be that at higher levels the factors which affect persistence of males and females have more in common as the females who persist may be those who are less affected by environmental factors. This study should also include male students for comparison, and also because only slightly more than half of the males who intended to enrol in a subsequent course actually did.

Interventions

The secondary purpose of this study was to develop possible intervention strategies which may help increase the persistence rates of students, both male and female, in computer science courses at the university level. The findings of the study seem to indicate that several of the variables in the model influence the persistence of students significantly. Thus, interventions which influence these variables may indeed result in a change in persistence. The interventions would seem to be of two types: those which must occur at the high school level or earlier and affect change before the student enters the introductory computer science course at the university, and those which may occur at the university level and affect change in the introductory course through environment or curriculum.

Interventions prior to university level. Interventions which must take place prior to university level are those which pertain to prior computer experience, previous computer courses, attitude to mathematics, tendency to stereotype, and self-confidence in computing. These intervention strategies should be made known to teachers of high school courses--computer science and otherwise, school counsellors, program planners, parents, and indeed to students themselves. Awareness on the part of these individuals is a critical first step to changing the present situation of persistence in university level computer science for both male and female students.

The first considerations relate to attitude to mathematics. Although attitude to mathematics was not included in the model for persistence of females in computer science, an indirect effect for attitude to mathematics resulted from the path analysis for females but not for males. It would seem that attitude to mathematics is a factor in persistence in computer science for females. Thus, further investigation of this relationship should occur and interventions which result in a more positive attitude to mathematics by female students should be considered. These interventions should focus on females while they are enrolled at the junior and senior high school levels. Programs which increase the student's enjoyment of mathematics (Armstrong, 1985; Brush, 1985), which increase the female student's awareness of the usefulness of mathematics in future courses (Sells, 1980), and which dispel the myth that college mathematics and science require "severe" dedication and hard work will do much to start changing the attitude to mathematics of female students.

In addition, teachers must be made aware of how important their attitude to mathematics and computing is on the attitudes towards mathematics and computing which their female students are developing. Kahle (1985) and Schubert (1986) both have related that effective, enthusiastic, and confident role models can influence the attitudes to and interest in mathematics and computing.

Of the variables included in this study previous computer experience seems to be one of the most important factors related to persistence in computer science for both male and female students. As this experience need not necessarily be related to computer science courses, it seems important that all students have access to computers and be instructed in their use. Since it is impossible to mandate that all families purchase computers for the home, this computer access must be made available through the schools; hence, it is important that schools receive funding so that they can provide a variety of opportunities for students to gain extensive computer use prior to leaving high school. Once computers are present, in sufficient numbers, in the schools, access to computers must be available to "all" students (Dubois & Schubert, 1986). All students, both male and female, must be encouraged to become effective and comfortable users of the computers. Marrapodi (1984), Gilliland (1986), and Hawkins (1985) have all related this need for active participation in computer-related activities by all students.

Awareness is a key to increased participation in computer use. Teachers must be aware of the positive relationship which seems to exist between extensive use of computers and persistence in computer science training. With this information they must work towards providing interesting and useful computer activities for their students--preferably in a wide range of subject areas. In addition to developing activities, they must strive to provide equal opportunity to both male and female students overcoming the perceived inequality of access which has been noted in the past (Hawkins, 1985; Lipkin & McCormick, 1986; Schubert, 1986). Likewise, parents should be aware that previous computer experience is an important factor in the persistence of males and especially, females in computer science. Hess and Miura (1985) observed that parents enrolled boys in special computer camps and activities more often than they enrolled girls, and also that parents purchased computers more frequently for boys than for girls. Thus, it is important that parents be aware of the importance of previous computer experience so that they can encourage girls to participate in computer activities and so that they can actively provide girls with opportunities for computer experience.

Previous computer science courses had negative relationships with persistence in computer science for students in both the male and female models. Thus, it would seem that computer science courses at the high school level, as presently outlined, do not have a positive effect on either the achievement level or the persistence of students in introductory computer science courses at the university level. Greer (1986) also noted that if "the underlying goal of high school computer science is university preparation, its value is suspect, especially in light of this (his) study" (p. 225). Results from this study would tend to agree with Greer's observation. If achievement in high school mathematics and science are strong predictors of success and persistence in introductory computer science courses at the university level (Campbell & McCabe, 1982; Oman, 1986;

Peterson & Howe, 1979) and high school computer science courses are not positively related to success or persistence, then it may be more appropriate for high schools to concentrate on providing strong backgrounds in mathematics and the sciences instead of providing introductory computer science courses at the high school level. Computer applications in these and other subject areas could provide a variety of computer experiences including word processing in the English classroom, problem solving skills in the mathematics and science classroom, graphics skills in drafting and applied arts courses, among others. Alternately, the curricula of high school computer science courses could be reviewed and further study carried out to determine what changes could be implemented in these courses which would result in a positive relationship between persistence in computer science and high school computer science courses. Such review of high school computer science curricula should have input from the faculty of the university computer science departments from throughout the province. This input and liaison would assist in generating a curriculum which is appropriate as a prerequisite to the university-level courses and increase the awareness of both high school computer science teachers and university instructors of the constraints, problems, and strengths of both parts of the computer science continuum.

However, as a result of the apparent strongly positive relationship between previous computer experience and persistence, emphasis should be placed on increased use of computers in all subject areas and increased access to computers for all students in the high school system and even earlier. Such a recommendation has far reaching implications for the professional development needs of teachers at these levels. If computer use is to occur in all subject areas and if teachers are to act as competent, confident, enthusiastic role models in computer use, extensive professional development in the use of the computer as a teaching tool will be necessary.

In addition, female students must be made aware of the importance of computer skills as well as mathematics and science courses if their future aspirations are in the computer or technology-related fields. As recommended by Ware, Steckler, and Leserman (1985) and Haring and Beyard-Tyler (1984) women who are actively employed in technological occupations should be invited into high school classes to act as role models and to encourage the participation of female students in technological programs as strategies which increase the persistence rates of females are of little value if the participation rates remain low.

In conclusion, it seems important that parents and teachers provide opportunities for students, especially female students, to have increased access to computers at the high school level and to provide a wide range of computer applications to create interest and enthusiasm for their use by the students. At the same time it is important that emphasis on computer use not overshadow the development of mathematics skills and attitudes as it may well be that these are more important factors in persistence of students in computer science than are computer literacy and computer skills.

Interventions at the university level. The major area of concern for intervention at the university level is the learning environment and its influence on achievement and persistence in the university-level computer science course. How the female student feels in the computer science classroom is a factor in the persistence of the female student enrolled in introductory computer science. Thus, it would seem important that both the lecture and laboratory instructors in computer science be aware of the concerns of the female student. The data reveal that females enrolled in Computer Science 110 are significantly less comfortable in the labs and in the lectures than are males in the same course. Efforts should be made to interview a sample of female students in order to determine what aspects of the lecture and lab experience they feel uncomfortable about. If lab assistants, for example, are not perceived as supportive by the female students, it may be desirable to arrange a professional development workshop through the Teaching and Learning Centre that would attempt to sensitize the lab instructors to the need for sensitivity and careful communication skills--both speaking and listening--when dealing with uncomfortable students of either gender. Also, it may be desirable for professors involved in the Computer Science 110 course to occasionally visit the labs in order to make more personal contact with the students and the lab instructors while in their teaching environment. Finally, simple survey forms could be occasionally distributed to the students asking them to appraise their reactions, both cognitive and affective, to the learning experiences of the previous week or other time period.

In their study of adult students in a computer literacy program Bostock, Seifert, and McArdle (1987) related that women were most comfortable, attained their highest grades, and persisted at a higher rate in computer courses which stressed a cooperative learning environment. Although the instructors of the introductory computer science courses may require that laboratory assignments be done independently, they may be able to increase the self-confidence and comfort levels of their female students by incorporating cooperative practice assignments in the laboratory or by encouraging partners in the earlier assignments until confidence in using the machines is gained.

It has also been suggested that enthusiastic, dynamic, interactive learning situations encourage the participation of female students in nontraditional classrooms (Armstrong, 1985; Duncan & Haggerty, 1984; Menzies, 1982). Females may also persist at a greater rate if they receive personal encouragement and recognition from the instructor. The university classroom is often an impersonal and cold environment, especially for students who have just left the smaller, more student-centred high school classroom. Connors (1987) related that there was less likelihood of stereotyping computer science in the smaller, more interactive college atmosphere. The same may well apply to the comfort level in the computer science course if more personal contact with students could be fostered.

By increasing the awareness of instructors to the varying needs of their students as well as to any subconscious biases or attitudes that they may have to females in computer science (Deptuck, Whelan, & Leuthy, 1985) a change in the atmosphere and attitudes in the classroom may result. Thus, a cooperative, interactive, friendly classroom or laboratory situation may indeed increase the comfort level of all students and hence, result in increased persistence. Most of the prior computer experience of students entering the first-year computer science program will have been gained through the use of microcomputers which tend to be more user friendly than the large mainframe computers. Thus, the learning environment could be made more user friendly for most students by using microcomputers. In fact, the learning environment in Computer Science 110 labs may be more comfortable for many students now as microcomputers were introduced in 110 labs in the January following the collection of data for this survey. A follow-up study to determine the effect of this change should be carried out using the same path analytical models. However, if the introduction of microcomputers has made a positive change on the comfort level of students it is imperative that lab assistants and professors consider that the initial fear of the mainframe may have only been delayed and a less threatening introduction to the mainframe should be planned.

Prediction of success, the measure of student self-confidence, related positively but weakly to persistence in computer science in the male model when tested for both male and female students. As self-confidence in computer science seems to be positively related to attitude to mathematics, previous computer experience and courses, and comfort level in the introductory computer science courses for female students, it seems important to stress those interventions which have been related to increasing comfort level and attitude to mathematics as well as increasing access to computers and their use. Although a well known technique in education, instructors in computer science, especially the often inexperienced lab assistants, may not be aware of the value of personal supportive feedback on students' written work. The occasional message of personal encouragement on written work returned from assessment, may be extremely helpful for less-confident and less-comfortable students. While difficult to implement with large groups of students, lab instructors could be encouraged to give this sort of encouragement when marking work and even a busy instructor can make encouraging comments on some of the test papers submitted for grading. Lab instructors can also increase the comfort level of students by making an effort to get to know the students and by encouraging them to come to him or her for assistance if they need a little extra help. Office hours for lab instructors could provide the opportunity for some one-on-one help for students, but the less-confident, less-comfortable students must be encouraged to make use of these opportunities and they must not be made to feel "dumb" when they do approach the instructor for extra help.

Achievement level in the first university-level computer science course was the variable which related most strongly with persistence for both male and females and as such warrants investigation. The models in this study did not provide a great deal of information about variables which may influence success except for the positive relationship of achievement and previous computer experience. However, the path coefficients in the fully recursive model seem to indicate that attitude to mathematics and comfort level in the computer science classroom should continue to be investigated as affective variables in the achievement level of females while comfort level and self-assessment in computer science should be further investigated as factors in achievement of male students. In addition, the studies by Campbell and McCabe (1982) and Oman (1986) would indicate that mathematics achievement should also be included in these ongoing investigations.

In conclusion, it seems important that at all levels of computer instruction that the learning environment be made as non-threatening as possible and that the instructor provide a supportive atmosphere in which the student can approach his or her studies enthusiastically with ready assistance. Likewise, it would seem important that students who are interested in pursuing computer-related careers should be made aware of the importance of previous computer experience before entering studies at the university level. Awareness of the variables related to persistence may be the key to increasing the persistence of students, male and female in the study of university-level computer science.

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Appendix A

Computer Science 110 Survey — Fall 1986

The following questionnaire is being distributed to students at the University of Victoria who are currently enrolled in Computer Science 110.

Please read each question carefully and fill in, using a soft PENCIL, the corresponding box on the MSR card attached to the survey. Hand in the questionnaire as well as the MSR card. Thank-you.

1. Your gender? a) Male b) Female
2. Which of the following best describes your age?
   a) Under 20 years b) 20 - 23 years c) 24 - 27 years
   d) 28 - 40 years e) More than 40 years
3. Before you began taking this course which of the following best describes your experience with computers?
   a) I had not used a computer before taking this course.
   b) I had used a computer extensively.
   c) I had used a computer a few times.
   d) I had used a computer only to play games.
4. If you have used a computer before taking this course identify the type you have had most experience with:
   a) Apple ll or lle b) Commodore c) IBM PC
   d) Radio Shack e) None of these
5. Does your family own a microcomputer?
   a) Yes b) No c) has owned but does not now
6. If your family owns (owned) a microcomputer, describe your use of it during the past 12 months.
   a) None because my family does not own a computer
   b) None even though my family owns a computer
   c) Only one or two times
   d) Occasionally
   e) Regularly
7. If, in the past 12 months, you have had access to computing facilities outside your home describe your use.
   a) None because I did not have access to a computer
   b) None even though I had access to a computer
   c) Only one or two times
   d) Occasionally
   e) Regularly
8. Did you complete Computer Science 11 or a computer studies course in high school?
   a) Yes b) No
9. Did you complete Computer Science 12 in high school?
   a) Yes b) No
10. Have you completed CSC 100 at U.Vic or an equivalent course at another university or college?
   a) Yes b) No c) Uncertain

11.If you have taken a C Sc course previously, identify the most recent year in which a course was taken.
   a) I have not taken a course previously
   b) 1985/86 c) 1984/85 d) 1983/84 e) before 1983/84
12.Have you used a computer in an employment situation?
   a) Yes b) No
13.Have you studied about computers on your own(self study)?
   a) Yes b) No
14.In which faculty are you enrolled?
   a) Arts & Science
   b) Education
   c) Engineering
   d) Human and Social Development
   e) Other
15.If you are enrolled in Arts & Science, please name the department in which you plan to major. If you are not in Arts and Science please answer e) None of the above.
   a) Biology
   b) Computer Science
   c) Mathematics
   d) Physics/Astronomy
   e) None of the above
16.If you are enrolled in Arts & Science, please name the department in which you plan to major.If you are not in Arts and Science please answer e) None of the above.
   a) Chemistry
   b) Economics
   c) Commerce
   d) Undecided
   e) None of the above
17.Which of the following best describes why you are taking CSC 110?
   a) a degree requirement
   b) a departmental recommended course
   c) general interest
18.Do you expect to take a computer course next semester?
   a) Yes b) No C) Undecided
19.Do you expect to take a computer course next year?
   a) Yes b) No c) Uncertain
20.In what geographical location did you complete Grade 12 (or equivalent)?
   a) Greater Victoria
   b) Vancouver Island (outside Greater Victoria)
   c) Greater Vancouver
   d) Other parts of B.C.
   e) Outside of B.C.
21.Which of the following best describes your background?
   a) Large urban centre (such as Vancouver)
   b) Moderate sized city (such as Victoria or Kelowna)
   c) Small city d) Rural
   e) Isolated area (no high schools locally)

22. Which of the following best describes the high school you attended?
   a) Large urban public high school
   b) Small urban public high school
   c) Rural high school
   d) Private high school
   e) Adult education high school equivalency program
23. Which of the following best descibes your career experience?
   a) I am training for my first career
   b) I am considering or training for a career change.
   c) I do not have career goals at present.
24. Which of the following best describes your predictions about your achievement in CSC 110?
   a) Confident I will be successful
   b) Hope I will be successful but have some concerns
   c) Do not expect to be very successful but expect I will pass
   d) Concerned that I will not complete the course
   e) Can not predict
25. Compared to your other classes, the atmosphere in CSC 110 lecture is
   a) more supportive and non-stressful than my other classes
   b) about the same as my other classes
   c) less supportive and more stressful than my other classes
26. Compared to your other classes, the labs and the help you receive with assignments in CSC 110 are
   a) more supportive and non-stressful than my other classes
   b) about the same as my other classes
   c) less supportive and more stressful than my other classes
27. Based on what you have experienced so far in CSC 110, how do you feel in the course personally (not academically)?
   a) very comfortable
   b) comfortable
   c) slightly uncomfortable
   d) very uncomfortable
   e) no opinion
28. Which of the following best reflects your feelings about mathematics?
   a) I really enjoy it
   b) I don't enjoy it but do reasonably well in it
   c) I don't enjoy it and I do poorly..
29. How much do you see computer science to be dependent on mathematics?
   a) You must be good in math to be good in C Sc.
   b) Some areas of C Sc. can be mastered without any math
   c) Large areas of C Sc. can be mastered without any math

30.Rate the job potential as you see it for women in general entering the computing field.
a) worse than for men b) equal with men c)better than men
31.Rate the job potential as you see it for yourself in the computing field.
a) No potential as my career goals are in another area
b) Little or no potential although I do have some interest in the computing area
c) some potential for me
d) good potential for me
32.Rate the job potential as you see it for women entering the computing field compared to the general employment market.
a) better opportunities b) equal opportunities
c) poorer opportunities
33.Rate the job potential as you see it for men entering the computing field compared to the general employment market.
a) better opportunities b) equal opportunities
c) poorer opportunities
34.Do you think that to be a good computer scientist you must think scientifically?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
35.Do you think that to be a good computer scientist you must be mechanically minded?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
36.Do you think that to be a good computer scientist you must be good at math?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
37.To be a good computer scientist one must be good with people?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
38.To be a good computer scientist one must be a good communicator?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
39.To be a good computer scientist one must be sensitive to peoples's feelings?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion
40.To be a good computer scientist one must be dedicated to your work?
a) Strongly agree b) Agree c) Disagree
d) Strongly disagree e) No opinion

Appendix B

Summary of the Path Analysis

Table B-1
Fully Recursive Model - Females

Endogenous Variables	Exogenous Variables: Attitude to Mathematics			Previous Computer Courses			Previous Computer Use			Age		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype	-.128	.000	-.128	-.043	.000	-.043	-.147	.000	-.147	-.195	.000	-.195
Comfort Level	.285	-.007	.278	.073	-.002	.071	.283	-.008	.275	-.196	-.011	-.207
Prediction of Success	.174	.135	.309	.166	.035	.201	.052	.136	.188	.061	-.077	-.016
Achievement	.142	.066	.208	-.157	.013	-.144	.166	.069	.235	.099	-.056	.043
Persistence	.065	.140	.205	-.165	-.045	-.210	.122	.147	.269	-.304	.015	-.289

	Endogenous Variables: Tendency to Stereotype			Comfort Level			Prediction of Success			Achievement		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype												
Comfort Level	.054	.000	.054									
Prediction of Success	-.082	.024	-.058	.449	.000	.449						
Achievement	-.001	.017	.016	.274	-.015	.259	-.034	.000	-.034			
Persistence	-.077	.009	-.068	.088	.134	.222	.045	-.015	.030	.440	.000	.440

Table B-2

Fully Recursive Model - Males

Endogenous Variables	Exogenous Variables: Attitude to Mathematics			Previous Computer Courses			Previous Computer Use			Age		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype	-.085	.000	-.085	.029	.000	.029	-.066	.000	-.066	-.146	.000	-.146
Comfort Level	-.020	.015	-.005	.041	-.005	.036	.244	.012	.256	-.070	.026	-.044
Prediction of Success	.043	.000	.043	-.132	.012	-.120	.325	.093	.418	-.017	-.012	-.029
Achievement	.060	.009	.069	-.148	-.021	-.169	.210	.125	.335	-.159	-.011	-.170
Persistence	.115	.046	.161	.000	-.116	-.116	.058	.247	.305	-.125	-.110	-.235

Endogenous Variables	Endogenous Variables: Tendency to Stereotype			Comfort Level			Prediction of Success			Achievement		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype												
Comfort Level	-.178	.000	-.178									
Prediction of Success	-.025	-.064	-.089	.357	.000	.357						
Achievement	-.006	-.043	-.049	.138	.076	.214	.213	.000	.213			
Persistence	.017	-.038	-.021	-.009	.170	.161	.108	.131	.239	.614	.000	.614

Table B-3
Hypothesized Model - Females

Endogenous Variables	Exogenous Variables											
	Attitude to Mathematics			Previous Computer Courses			Previous Computer Use			Age		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype	-.128	.000	-.128							-.156	.000	-.156
Comfort Level	.278	.000	.278	.071	.000	.071	.275	.000	.275	-.207	.000	-.207
Prediction of Success	.170	.137	.307	.172	.032	.204		.123	.123		-.077	-.077
Achievement				-.194	.000	-.194	.265	.000	.265			
Persistence		.036	.036	-.170	-.078	-.248	.139	.155	.394	-.292	-.026	-.318

	Endogenous Variables											
	Tendency to Stereotype			Comfort Level			Prediction of Success			Achievement		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype												
Comfort Level												
Prediction of Success	-.099	.000	-.099	.449	.000	.449						
Achievement												
Persistence				.128	.000	.128				.451	.000	.451

Table B-4
Hypothesized Model - Males

Endogenous Variables	Exogenous Variables: Attitude to Mathematics			Previous Computer Courses			Previous Computer Use			Age		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Prediction of Success	Variable			-.098	.000	-.098	.409	.000	.409			
	Not Retained											
Achievement	In			-.153	.000	-.153	.366	.000	.366			
Persistence	Model			-.016	-.105	-.121	.082	.270	.352	-.122	.000	-.122

Endogenous Variables	Endogenous Variables: Tendency to Stereotype			Comfort Level			Prediction of Success			Achievement		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Prediction of Success	Variable			Variable								
	Not Retained			Not Retained								
Achievement	In			In								
Persistence	Model			Model			.105	.000	.105	.621	.000	.621

Table B-5

Hypothesized Model for Males - Tested for Females

Endogenous Variables	Exogenous Variables											
	Attitude to Mathematics			Previous Computer Courses			Previous Computer Use			Age		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Prediction of Success	Variable Not Retained			.159	.000	.159	.228	.000	.228			
Achievement	In			-.194	.000	-.194	.265	.000	.265			
Persistence	Model			-.180	-.073	-.253	.149	.150	.299	-.317	.000	-.317

	Endogenous Variables											
	Tendency to Stereotype			Comfort Level			Prediction of Success			Achievement		
	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Prediction of Success	Variable Not Retained			Variable Not Retained								
Achievement	In			In								
Persistence	Model			Model			.112	.000	.112	.469	.000	.469

Table B-6
Hypothesized Model for Females - Tested for Males

Endogenous Variables	Exogenous Variables: Attitude to Mathematics — Direct Effect	Indirect Effect	Total Effect	Previous Computer Courses — Direct Effect	Indirect Effect	Total Effect	Previous Computer Use — Direct Effect	Indirect Effect	Total Effect	Age — Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype	-.094	.000	-.094							-.141	.000	-.141
Comfort Level	-.005	.000	-.005	.036	.000	.036	.255	.000	.255	-.044	.000	-.044
Prediction of Success	.088	.000	.088	.053	.015	.068		.105	.105		-.015	-.015
Achievement				-.143	.000	-.143	.358	.000	.358			
Persistence				-.023	-.091	-.114	.112	.235	.347	-.119	-.001	-.120

Endogenous Variables	Endogenous Variables: Tendency to Stereotype — Direct Effect	Indirect Effect	Total Effect	Comfort Level — Direct Effect	Indirect Effect	Total Effect	Prediction of Success — Direct Effect	Indirect Effect	Total Effect	Achievement — Direct Effect	Indirect Effect	Total Effect
Tendency to Stereotype												
Comfort Level												
Prediction of Success	-.025	.000	-.025	.413	.000	.413						
Achievement												
Persistence				.020	.000	.020				.643	.000	.643

Vita

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