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ABSTRACT

This study was designed, using a path analytic model, to assess the relative impact of different factors on science concentration decisions made by grade 10 high school students (N=237). Included in the model were selected demographic and socioeconomic factors, academic abilities factors (including logical thinking), indicators of home and school support, attitudes toward science, and students' science enrollment plans. Results indicate that students (especially females and blacks) tended to avoid advanced and quantitative science courses. Student attitudes toward science were low, especially their motivation and self-confidence in learning science. Though they were higher achievers, females expressed less enjoyment in learning science than males. Males, more than females, stereotyped science as a male domain. Attitudes and past performance appeared to influence course plans for both males and females. Among the attitudes, student motivation and usefulness of science were the most important predictors for course plans. These and other results suggest that: (1) improved achievement in junior high school years should be emphasized; (2) teachers and parents should motivate and encourage students to select more science courses; and (3) the unique value and usefulness of each science course should be explained to students as early as possible. (Author/JN)

FACTORS INFLUENCING HIGH SCHOOL STUDENTS' SCIENCE ENROLLMENTS PATTERNS: ACADEMIC ABILITIES, PARENTAL INFLUENCES, AND ATTITUDES TOWARD SCIENCE

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Abstract

This study was designed, using a path analytic model, to assess the relative impact of different factors on science concentration decisions made by high school students. Included in the model were selected demographic and socioeconomic factors, academic abilities factors, indicators of home and school support, attitudes toward science, and students' science enrollment plans.

The subjects were 237 tenth grade students in two schools of a Midwest school system. Two instruments were used to collect data related to the selected factors. School records were used to obtain math and science grades and the California Achievement Test scores from the previous school year. Descriptive, relational, and model-fitting analysis were used. The results indicated that students, especially females and blacks, tended to avoid advanced and quantitative science courses. Student attitudes toward science were low, especially their motivation and self-confidence in learning science. Though they were higher achievers, females expressed less enjoyment in learning science than males. Males, more than females, stereotyped science as a male domain. Attitudes and past performance appeared to influence course plans for both males and females. Among the attitudes, student motivation and usefulness of science were the most important predictors for course plans. The path analysis showed that males and females differed in the order of importance and kinds of factors that shape their concentration decisions. For males, general achievement, motivation, and family climate were the most important factors to influence course plans positively and directly. In contrast, usefulness of science, general achievement, and teacher support were the most important factors influencing female course plans. Home environment contributed more to male attitudes toward science and consequently to science concentration decisions. These results suggest that improved achievement in junior high school years should be emphasized; teachers and parents should motivate and encourage students to select more science courses; and the unique value and usefulness of each science course should be explained to students as early as possible.

There is a developing fear that science and technology in the United States are lacking in two critical areas. First, there is a developing shortage of highly qualified scientists, and second, the scientific literacy of the population is not considered to be adequate (National Science Foundation, 1983).

Two trends were found to contribute to the above situation. These are the claimed shortage of qualified mathematics and science teachers (National Science Foundation and Department of Education, 1980) and the decline in science students' enrollments, including minorities and women, in high school (Helgeson, et al., 1977; National Science Foundation, 1983).

A large number of students are graduating from high school scientifically and technologically illiterate. According to the National Assessment of Educational Progress 1978, there has been a continual decrease in science achievement of 9-, 13-, and 17-year old students in schools, nationally. A trend found to be related to this phenomenon is the decrease in students' enrollments in science courses throughout the school years (Helgeson, et al., 1977; Miller, 1978).

Research in science teaching indicates most middle/junior high school students are not ready to do the formal reasoning required for them to select advanced science courses. Consequently, students' choices of science courses are restricted. Added to the above, students' attitudes toward science are dropping as they move to higher grade levels. The decrease in attitudes toward science will in turn be affecting science enrollments drastically.

The problem, however, is more complex than it appears. Previous research on this issue showed that the decline in science and mathematics enrollments is related to many interrelated factors such as sex, race, students' academic abilities, social-environmental, teaching and methods of instruction, and students' attitudes toward science.

Fennema and Sherman (1977, 1978) found differences in attitudes between the two sexes and related these differences to mathematics achievement. Armstrong (1980), Lantz (1980), and Eccles (1983) indicated that differences in attitudes have predictive value in the voluntary election of optional high school mathematics courses. Levin and Fowler (1982) found differences in attitudes toward science with respect to gender, secondary grade, and science program. Riley (1982) found that students' attitudes and perceptions toward science/science teaching, achievement and some selected demographic variables such as race and sex were related. None of the studies reviewed, however, provided a comprehensive framework t explained causally decisions to select science courses at high school taking into account the interplay of multiple factors.

This study was designed to examine and explain the relationship between several cognitive, affective, and social characteristics of students and their choice of science courses in grades nine through eleven. The objective of this was to improve our understanding of decision behavior among high school students regarding the studying of science, given the continuing decrease of certain science courses enrollments, and to improve the understanding of the disproportionate enrollment figures among minorities and women. It is assumed that such understanding will assist decision makers in finding what, how, and when science courses should be taught at school.

Conceptual Framework

According to the review of literature, past achievement, sex, parental support, teacher support, and attitudes toward science play important roles in students' decision to select science courses at school. Upon analysis of these factors, many psychologists emphasize the importance of attitudes in academic choice and also in explaining sexual differences in math or science training. Perceptions of self ability and the incentive value of the subject were hypothesized to influence behavioral choice, as well. Individual differences of these attitudes are caused by differentiated past experiences and by differential information and encouragement from parents or teachers about the importance of doing well at a certain task. Based on this theoretical framework, a model was developed to explain students' science concentration decisions while studying at high school. Included in the model were selected demographic and socioeconomic factors, academic abilities factors, indicators of home and school support, attitudes toward science, and students' science enrollment plans. Table 1 presents the specification of the model . Figure 1 shows the developed path analytic model. As seen in Figure 1, the proposed path model links academic choice to attitudes: self-confidence in ability, motivation and

TABLE 1

Model Specification

Personal Characteristics	Learning Environment	Attitudinal/ Motivational Characteristics	Behavioral Choice
-Demographic factors: Sex Race -Socioeconomic factors: o Parents' occupation characteristic o College plans o Availability of science supplies at home -Academic abilities: o Past science and math grades o Past achievement o Reasoning abilities	-Home and school factors: o Father,mother, and family impact o Teacher and curriculum impact	-Attitudes toward science: o Confidence in learning science o Effectance motivation and interest toward science o Beliefs about the usefulness of science o Perceptions of science as a male domain	-Science concentration decisions: o Science enrollment plans

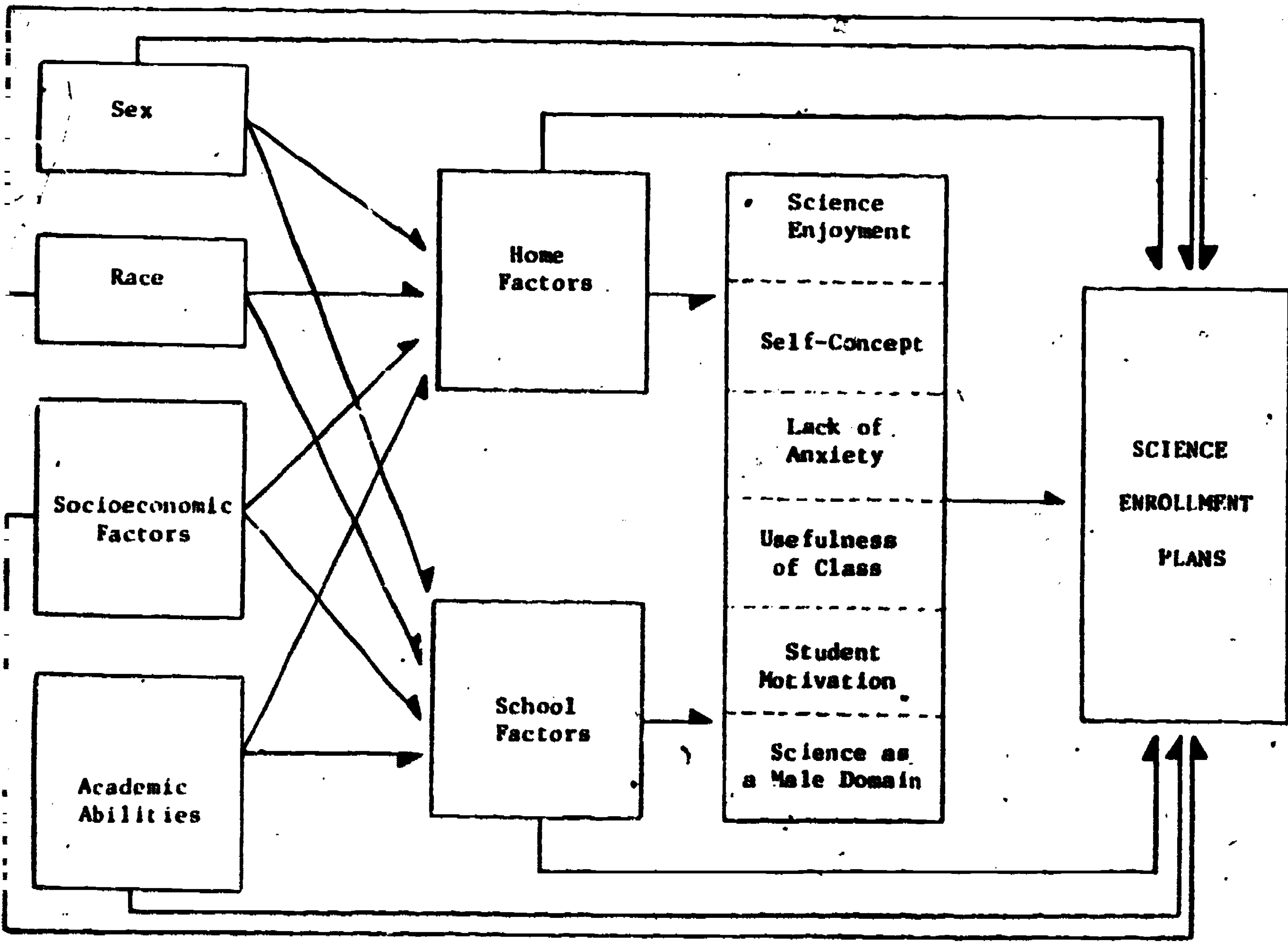

Figure 1 - General Model of Enrollments Plans

enjoyment, usefulness of subject, and perception of science as a male domain. It also specifies the relation of these constructs to teachers, and parents encouragement, demographic and socioeconomic characteristics, and academic abilities and past performances.

Purpose

The purpose for conducting the study was twofold: the first was to determine how well the factors proposed in the model relate to students' choice of a certain level of science course sequence in grades nine through eleven, and to develop a 'best' model that explains this decision behavior. The second purpose was to explain the disproportionate science enrollments between males and females. The general model proposed is particularly useful in analyzing sex differences in students' decisions to select a certain sequence of science courses. Specifically, the research was an attempt to answer the following major questions:

1. How and to what extent do students, in general, avoid science?
2. How and to what extent do students' enrollment plans relate to the various factors proposed in the model?
3. Do males and females differ in kinds of factors influencing their attitudes and perceptions toward science, and science enrollment plans?

The path model provided the means for:

a. Testing the relative effects of the variety of different types of factors on decision making regarding the taking of certain sequence of science courses.

b. Testing whether academic abilities and past performance, home environment and demographic characteristics have main and direct effects on students' decisions to study science, or whether they determine decisions by influencing students' perceptions and attitudes and these in turn determine students' decisions for a certain sequence of science courses through the high school period.

c. Identifying differences between female and male groups. Once these differences are identified, a search for the causes of being in different levels of science courses is made for males and females.

The significance of these questions was to provide educators and practitionners with information on the characteristics of students who opt for different types of science courses and provide evidences on the factors behind these differences.

Procedures

Subjects

A total of 237 tenth grade students from a Midwest school system participated in the study. Forty-six percent (110 students) of the sample were males and 54 percent (127 students) were females. The majority of these subjects were whites (211 students), while 16 percent (26 students) were non-whites. The non-whites were mainly Blacks, American Indians, Asians and Middle Easterners. The percentage of non-whites in the whole population of tenth grade students ranged from 20 to 30 percent.

Measures

In order to assess the different factors proposed in the model constructed, two instruments were developed. The first instrument was a questionnaire. It was developed in two parts. The first part contained demographic and socioeconomic information about the student, science courses in which students were presently enrolled, past courses they took, and future courses they expect to take, students' expectations and perceptions of their parents' encouragement to attend college, and provision of science equipment at home. The second part contained the following subscales:

Father Support Scale

Mother Support Scale

Family Climate Scale

Teacher Support Scale

Teacher Enthusiasm Scale

Student Choice Scale

Science Enjoyment Scale

Self-Concept Scale

Lack of Anxiety Scale

Usefulness of Science Class Scale

Student Motivation Scale

Science as a Male Domain Scale

The first six subscales measure father, mother, family, and teacher support to study science as perceived by students reflecting to a certain degree the home and school influence. The last six subscales measure students' attitudes and perceptions to cience. The items of the 12 subscales used a

Likert Scale. Each response was given a score from 1-5 with the weight of 5 corresponding to the most positive attitude.

The majority of these items were adopted and modified slightly from the affective items developed by the National Assessment of Educational Progress in their 1977 survey. The grouping of the majority of the items into the identified subscales was based on the factor analysis done by Riley II and Napier (1982). The computed subscale reliability coefficients (Cronbach Alpha) of the grouped items in this study ranged from 0.65 to 0.86.

The second instrument was in the form of a test measuring students' reasoning abilities that were hypothesized to be important in course plans decisions. The test was constructed by selecting items from the Group Assessment of Logical Thinking (GALT) developed by Yeany, Roadrangka and Padilla (1983). The selected items measured six logical operations that are needed to acquire and comprehend science concepts. They were:

Conservation

Proportional Reasoning

Controlling Variables

Probabilistic Reasoning

Correlational Reasoning

Combinatorial Reasoning

The computed reliability coefficient (Cronbach Alpha) for these items was 0.79. The two instruments were administered together during one class period (55 minutes). The students were asked to fill out the attitudes questionnaire first and then the logical thinking ability test. This order was followed to avoid the influence of the test on students' attitudes measured by the first questionnaire.

In addition to the questionnaire and the test, several measures were taken directly from the students' records. These measures included math and science grades, from the previous year and California Achievement Test Scores--reading, math, and total.

Variables and Statistical Analysis

Descriptive, relational, and model-fitting analysis were used. A dependent variable 'Science Concentration Decisions' was studied in relation to a number of independent variables. The dependent variable was created from three separate questions that measured the type, if any, science course was taken in grades nine or ten and decided to take in grade eleven. The created variable had a scale of six levels, ranging from the least to the most rigorous sequence. Number and types of courses were taken into consideration in creating this scale. The most concentrated sequence consisted of the following courses: Biology, Physical Science, and Advanced Placement Chemistry, and the least concentrated sequence consisted of one Environmental Science or a similar course in rigorousness in the span of the three years of high school.

Three sets of independent variables were used. These included demographic, socioeconomic and academic variables. The demographic variables were sex and race. The socioeconomic variables included the relevance of father's and mother's occupation to science, college plans and provisions of science kits or equipment at home. The academic abilities variables included past math grades, past science grades, past school achievement and reasoning abilities in science.

Other types of variables, the mediators, were identified. These are variables that were treated as both dependent or independent variables, depending on their location in the path model. These variables are believed to intervene between science concentration decisions and the demographic, socioeconomic, and academic abilities measures mentioned earlier. The mediators included parental and family influence, school influence, and attitudes toward science.

In the model-fitting analysis, the demographic, socioeconomic, and academic abilities variables were referred to as exogenous variables and all other variables regarded as being caused by every variable to their left in the diagram, are referred to as endogenous variables. Both the direct and indirect effect between a pair of variables placed in a presumed causal sequence were estimated. The direct effect is represented by the standardized beta coefficients (Bj) estimated by the Ordinary Least Square (OLS) regression equations, while the indirect effect through a third variable can be estimated by the product of the direct path coefficients that intervene.

Findings

Various results and conclusions were drawn from the data analysis. They were related to the following major areas:

<u>Science Enrollment Patterns</u>

Univariate statistics showed around 50 percent of the subjects limit their science education to one or two science courses in the span of the three years of high school considered in the study (grades 9-11). The other 50 percent planned for three science courses, however, only 27 percent planned to take the most rigorous sequence including courses in physical science, biology, regular or advanced chemistry. Total enrollment figures over the three years showed that enrollments in physical science courses, environmental science courses, and advanced placement courses were lower than enrollments in regular biology courses, regular chemistry, and earth science courses. Figure 2 represents the distribution of the different science courses enrollments for both males and females.

When examining the course enrollment patterns by sex, the data showed that females and males planned for different types of science courses. More females than males planned to take Regular Biology (females: 93 percent; males: 85 percent), Earth Science (females: 58 percent; males: 38 percent), and Regular Chemistry (females: 65 percent; males: 43 percent). On the other hand, more males than females planned to take Environmental Science (males: 15 percent; females: 6 percent), Physical Science (males: 33 percent; females: 24 percent), and Advanced Placement Chemistry (males: 21 percent; females: 11 percent).

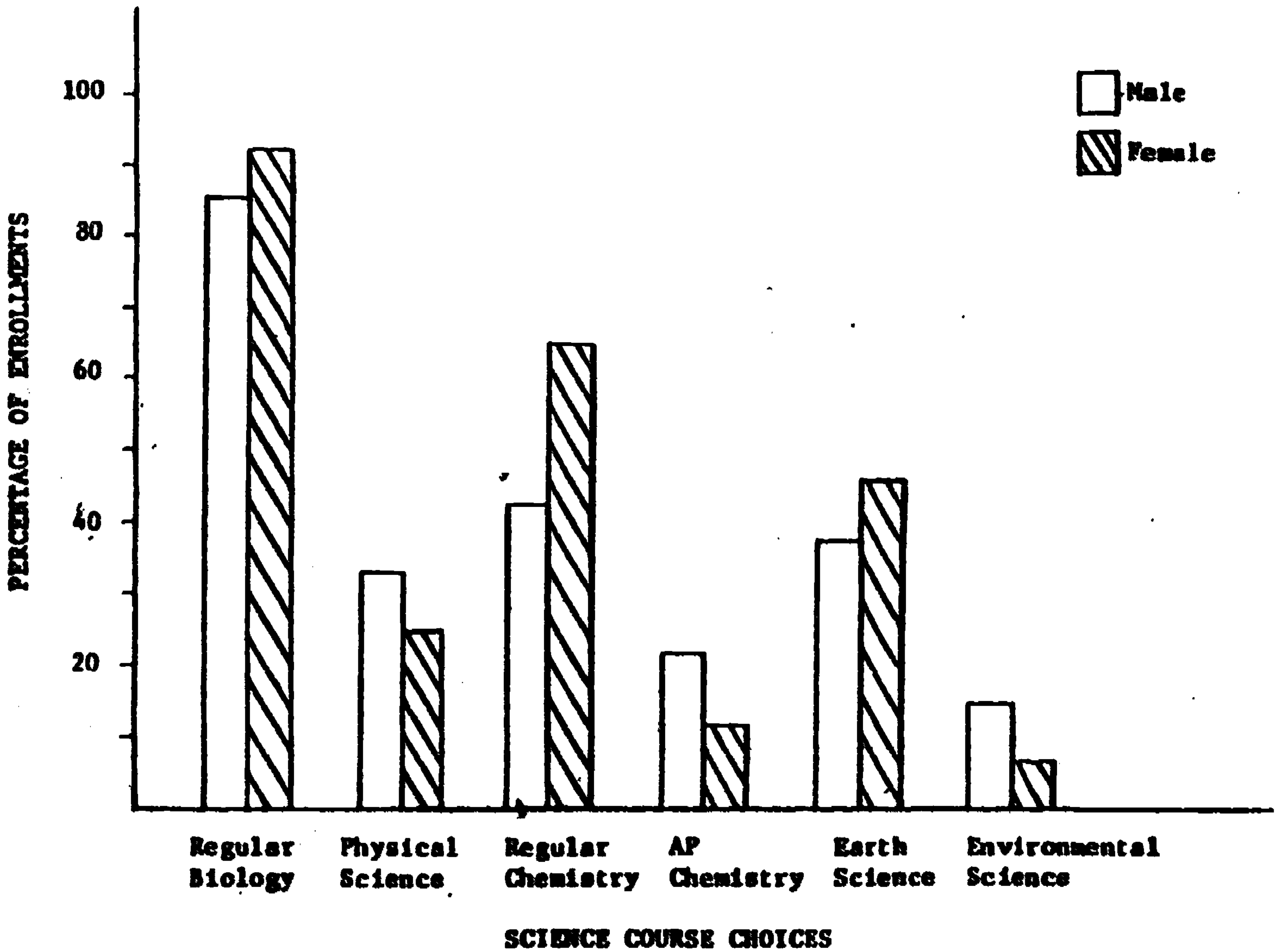

Figure 2 - Percentages of Science Enrollments by Course for Males and Females

When the enrollment data were examined by race, blacks showed the highest decrease in science course enrollment as they moved to higher grade levels. Twenty-six percent of the blacks did not plan to take a science course in grade eleven. In comparison, the percentages of the whites and Asian racial groups who did not plan to take science in that grade were 13 and 14 percent, respectively.

Demographic Differences: Attitudes and Abilities

The data on the attitudinal subscales showed that most of males' and females' attitudes toward science were low (mean score < 3.5), especially their motivation (2.48) and self-confidence (3.11) in learning science. When comparisons were made between females and males, few significant differences emerged. These differences are shown in Table 2. Females expressed less enjoyment and self-confidence in learning science than males though they were higher achievers. When comparisons were made across race, blacks showed more positive attitudes toward science, especially subject enjoyment.

Model-Fitting

The path analysis for the total sample showed, in line with results from multiple regression analysis, that Total Achievement has the strongest direct effect on science concentration decisions (path coefficient =.36). From the attitudes measures, Science Enjoyment and Usefulness of Science Class were also found to have direct effects on course plans (path coefficients were 0.15 and 0.14, respectively) . These attitudinal measures were, in turn, influenced primarily by Teacher Enthusiasm and Mother Support. Their path coefficients ranged from 0.21-0.44.

TABLE 2

Significant Differences between Males and Females: Attitudes and Academic Abilities

Subscale	Sex	N	$\bar{X}$	S^2	t-Test	DF	P
Science Enjoyment	Male Female	110 127	3.42 3.19	0.550 0.324	2.61	235	0.010**
Self-Concept	Male Female	110 127	3.24 2.99	0.618 0.534	2.56	235	0.010**
Lack of Anxiety	Male Female	110 127	3.56 3.30	0.374 0.431	3.11	235	0.002**
Student Motivation	Male Female	110 127	2.62 2.36	0.594 0.412	2.78	234	0.006**
Science as Male Domain	Male Female	110 110	1.80 1.27	0.538 0.186	6.81	234	0.000**
Past Math Grades	Male Females	78 111	2.57 2.93	1.014 0.723	-2.69	187	0.008*
Achievement: Reading	Male Female	80 112	636 659	4325 4453	-2.33	190	0.021*
Achievement: Total	Male Female	80 112	628 652	3757 3588	-2.77	190	0.006*

* $p < 0.05$

** $p < 0.01$

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Since the effect of sex was an important goal of in this study, only the separate path analysis for males and females are represented in Figure 3 and 4, respectively. For males, Student Motivation emerged to have the strongest direct effect (path coefficient = .20) on course plans among all attitude measures. Again, the male's path model showed that the strongest direct influence was Total Achievement (path coefficient = .49), indicating the important role of past performance for males' decisions. The variables in this model explained 45 percent of the variance in course plans for the males. In contrast, the path analysis for the females showed that Usefulness of Science has the strongest direct effect (path coefficient = .29) on science enrollment plans. Next, in order of importance were Total Achievement (path coefficient = .25) and Father Support (path coefficient = .25). For females, Family Climate was not as important as it was for males in contributing to the positive attitude of males, such as their motivation. The variables in the female path model explained 33 percent of the variance in course plans.

Discussion

The science enrollment patterns indicated that science enrollments are low for courses of a more quantitative nature and for courses that are more difficult in subject matter. This finding was consistent with other reports and research studies on science and math enrollments and which indicated that enrollments in science and math courses become low and fewer advanced science courses are elected when science is not required (School District

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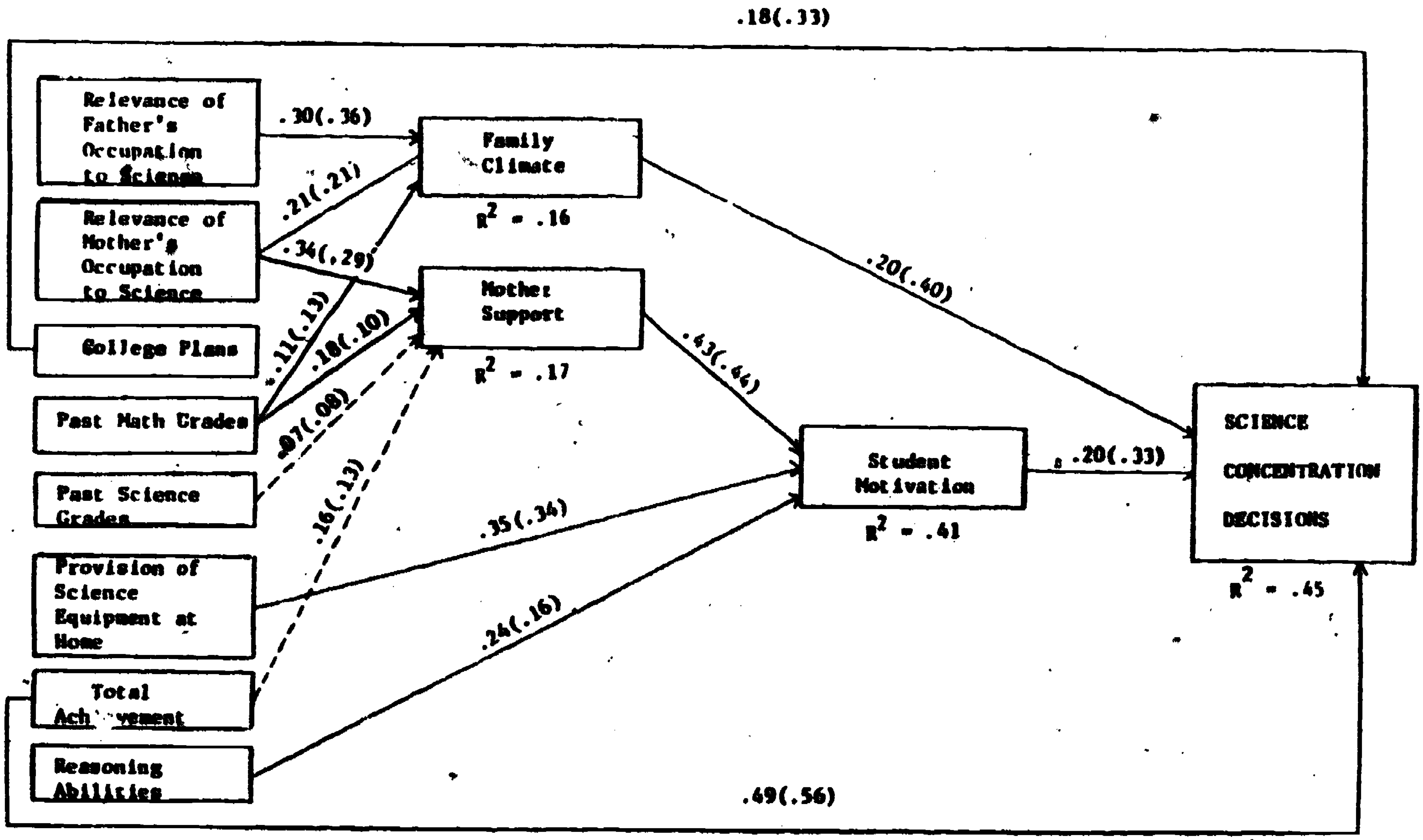
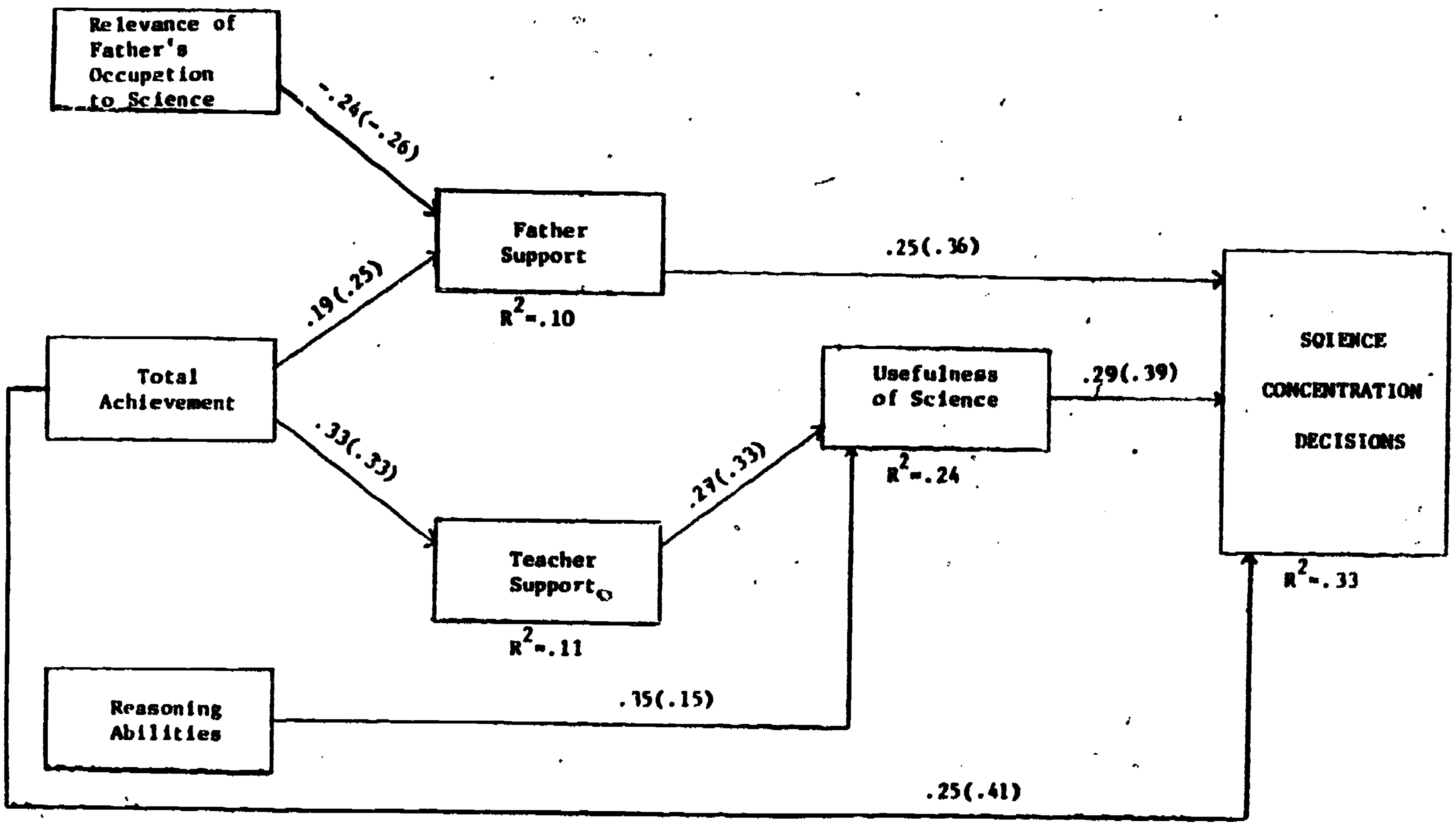


NOTE: The values in parantheses represent zero-order correlations; the other numbers are standardized path coefficients. All except the dotted paths are significant at the .05 level.

Figure 3 - Recursive Path Diagram of Factors Affecting Level of Science Concentration Decisions for the Males (N = 110)



NOTE: The values in parantheses represent zero-order correlations; the other numbers are standardized path coefficients. All paths are significant at .05 level.

Figure 4 - Recursive Path Diagram of Factors Affecting Level of Science Concentration Decisions for the Females (N = 127)

Sex and Race Equity Assessment Report, 1983; Michigan Peer Newsletter, 1977; NAED, 1978; Miller, 1978; Helgeson, 1977).

Males and females differ in their choice of science courses. This difference with regard to type of science course preferred was in agreement with many previous reports on math and science enrollments. Hofstein et al. (1977), and Ormerod and Duckworth (1975) reported that more males tend to ito the physical sciences or the more advanced courses such as physics and chemistry, than females. The fact that fewer females than males tend to take more advanced science or math courses in high school explain, to a certain extent, the reports made by many that engineering and science professions tend to be male-dominated (Vetter, 1978; Odegaard, 1978; U.S. Department of Health, Education and Welfare, 1977).

Students, in general, appeared not to have strong positive attitudes toward science. This result was especially noted for the motivation and self-concept scales. Students show low participation level in science related activities when they are not required for science courses. Sex differences were found for the attitude of science enjoyment, students' motivation, and the perception of science as a male domain, but not for the usefulness of science class. The fact that males perceived science as more enjoyable, were more motivated, and expressed more self-confidence in learning science was consistent with many previous research findings (Riley II and Napier, 1982; Eccles 1983; Fennema and Sherman, 1978, 1977; Ware and Steckler, 1983; Levin and Fowler, 1982). Males stereotyped science as a male domain more than females did. This result agreed with previous findings (Levin and Fowler, 1982; Sherman, 1980; Fennema and Sherman, 1978,1977). However, this factor did not influence course plans significantly for either sex group. As for academic abilities, the females of this study were higher achievers than males and had math grades in the previous year that were as good as the males' grades. This interesting finding suggests, to a certain extent, that the non-choice of advanced and more quantitative science courses, Physical Science and Advanced Placement Chemistry, by females compared to males cannot be the result of poor capabilities on the part of females, as implied by Benbow and Stanley's (1980) conclusions. Benbow and Stanley (1980) claimed that, because males have higher mathematical abilities than females, sex diffrences in achievement and attitudes are produced in favor of the males. Therefore, one might conclude that other factors than achievement and aptitude are influencing the females' choice of science courses.

The model-fitting analysis for showed that the sex difference in the choice of a science concentration was partially explained by the finding that males enjoyed science more than females did. This result was in agreement with Ware and Steckler (1983) findings and in disagreement with Eccles (1983). Ware and Steckler (1983) reported both a sex difference on that measure and a significant relation between science enjoyment and science concentration. Eccles (1983) reported that the subjective value of the task, rather than subject enjoyment, was the most important mediator of sex differences in mathematics course enrollments.

The results of the separate path analysis showed that males and females differed, at least to a certain extent, in the kinds of factors that shape their concentration choices. For the males, general achievement followed by students' motivation and family climate were the most important factors to influence course plans positively and directly. In contrast, usefulness of science class followed by general achievement and teacher support were the most important factors to influence females' course plans. Reasoning abilities affected males' and females' attitudes differently. For males, they affected students' motivation, while for females they affected their perception of the value and usefulness of science courses. Home environment, in terms of mother's and family's support and encouragement, appeared to be contributing more to males' attitudes toward science and consequently their science concentration decisions.

On the basis of these findings, the study suggests the following:

1. Science curricula, before the tenth grade, should be revised to assure improvement in science achievement. It was noted that high achievers tended to select the most rigorous science course sequence during high school years. This is not surprising since it is a known fact that science courses need sequential background, academic, and mathematical abilities. This is especially true for advanced science courses and science courses that are more quantitative in nature.

2. Students, especially females, should be guided as early as possible to perceive the value and usefulness of the different types of science courses. According to the results of this study, usefulness of science class was related positively to science enrollment plans.
3. Greater emphasis should be placed on developing students' interest and motivation. Both parents and teachers should support, encourage, and motivate students to do extra curricula work like reading science books, attending science lectures, watching science shows and developing science hobbies. They should be more supportive and encouraging for more rigorous science courses.
4. Interventions strategies to improve students' attitudes, especially their motivation, their perceptions of the value and usefulness of science, and achievement should be designed, implemented, and evaluated if science is to remain elective.
5. Since the results of this study showed that the problem of low enrollments lies in specific types of science courses, future studies shoud investigate, in a causal framework, the specific factors that lead to the low enrollments in the specific science subjects, namely, physical science and advanced placement courses. Courses offered at grade twelve such as physics and advanced placement physics should be taken into consideration in these studies.

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