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ABSTRACT

Research from sociology, science education, mathematics education, and psychology, as well as data from the National Assessment of Educational Progress (NAEP) indicate some of the causes of and potential solutions for sex inequities in science education. NAEP has indicated that 13- and 17-year-old girls have strong negative attitudes toward science and have little belief that the discipline can be useful to them. Research suggests that social factors (role models and sex stereotypes), educational factors (enrollment patterns, adult expectations, and class activities), and personal factors (spatial visualization) all contribute to this negative attitude. Possible remedies include adaptation of teaching strategies to female student needs, use of experiments that would enhance girls' spatial abilities, and incorporation of structured lab work. A national study has identified 10 teaching factors that affect retention of girls in science, including attractive classrooms, nonsexist teacher-developed materials, teacher awareness of sexism, and teacher encouragement of extracurricular activities. (LP)

Girls in School/Women in Science: A Synopsis

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Introduction

The following passage describes why inequities in science education are a particular problem.

> Our children and our students are participants in a complex process that equips one sex with math, science, and technical skills indispensable to functioning in the adult world, while it fails to encourage the same development in the other sex. Although the lives of individual women are the most negatively and directly affected, the loss to both sexes is immense. (Skolnick, Langbort, & Day, 1982, p. 2)

In the United States women comprise approximately 50% of the work force, yet only 9% are employed as scientists and engineers. Factors contributing to this situation have been analyzed in research studies in both the United States and Western Europe. Explanations for the lack of women in science have ranged from differences in spatial abilities linked to a sex-linked gene (Head, 1979) to differences in early childhood toys and games (Hardin & Dede, 1973). Although societal, educational, and personal factors are all involved, differences within the science classroom may be the basic reason why fewer women study science or pursue scientific careers.

Rationale

Although the lack of women in advanced science courses and in scientific and technological careers is accepted, the causes of this situation are argued. Some maintain that society itself is responsible; others argue that biological differences are the reason; still others suggest that Western culture is at fault. The pervasiveness of the problem and the complexity of its underlying causes defy simple solutions. In the past, researchers have examined sociological, cultural, biological, or educational factors in isolation. Although their studies have explicated the complexity of the problem, they have provided few pragmatic solutions.

This paper synthesizes previous research from sociology, science education, mathematics education, and psychology with current data from the National Assessment of Educational Progress (NAEP) in the attempt to identify causes and to formulate practical solutions.

Problem

Both the 1977 and 1982 National Assessment of Educational Progress' surveys of science contained items assessing both understanding of science and attitudes toward science (NAEP, 1978a; Hueftle, et. al., 1983). Achievement differences have been found between boys and girls at ages 9, 13, and 17. In 1977, girls averaged between 1.6 to 2.5 percentage points below the national mean on every cognitive item; while in 1982 the difference widened to 1.7 to 6.7 points below the mean. In order to understand these achievement differences, responses to questions concerning attitudes toward, opportunities in, and beliefs about science have been analyzed (Kahle & Lakes, 1983). In 1977, girls' responses to National Assessment items concerning opinions of science classes and feelings toward science as a career are consistently negative. Thirteen and, especially, 17-year-old girls respond that science courses consist of 'facts to memorize,' and they describe science classes as 'boring.' Girls also answer that they do not like to attend science classes and are often afraid to ask questions. Although 9-year-old girls respond that science does not make them feel 'successful,' most of their feelings are positive and comparable to those of 9-year-old boys. However, by ages 13 and 17, girls state that not only does science fail to instill feelings of 'confidence,' 'success,' or 'curiosity,' but also that it makes them feel 'stupid.' Responding to questions concerning science as a career choice, 13 and 17-year-old girls feel that working in science would not 'be fun,' would addition, fewer girls than boys want to 'work with scientists to solve problems,' 'make field studies; or 'read science articles.' They are less interested in learning about science careers. These findings have been substantiated by the responses to identical items in the 1982 survey.

Additional responses provide insights into the girls' perceptions of science and its impact on their everyday lives. For example, 17-year-old females find science useful in choosing foods and vitamins as well as in cooking, but they do not consider science involved in driving a car. Additional data indicate that neither 13 nor 17-year-old girls think that they use scientific methods in solving problems or in planning their lives. Generally, secondary school girls have little faith in science's ability to solve problems concerning agriculture, meteorology, energy, warfare, overpopulation, and conservation. Female responses to attitudinal items overwhelmingly document poorer attitudes toward science, less understanding of science, and less interest in scientific careers.

Research

Since poor attitudes are directly related to lower achievement levels (McCloske, 1976) and to lower enrollments in elective science courses, factors contributing to negative attitudes must be understood and ameliorated. Three types of factors have been identified: social (role models and sex role stereotyping); educational (enrollment patterns, parent/teacher expectations, classroom and extracurricular activities); and personal (spatial visualization). These specific factors have been selected because research substantiates their effects on the learning of science by women.

Societal Factors

One societal factor affecting attitudes toward, achievement in, and attrition from science by women may be the lack of role models (VanFossen, 1977; Smith, 1974; Graham, 1970). In 1950 the U.S. Department of Labor ... primarily employed in only 20 of the 420 jobs listed in the census of occupations; by 1970 that fact had not changed (U.S. Department of Labor, 1980). Skolnick, et al. (1982) relate that although women constitute 71% of teachers and 99% of secretaries, they make up only 4% of engineers and 1.2% of electricians. In secondary schools, only 24% of science teachers are women, and it may be assumed that most of them teach biology. Female role models are not prevalent in science.

However, Vockell and Lobonc (1981) in a study of coeducational and girls' schools found that the presence or absence of female science teachers did not influence girls' enrollment or achievement in science. Rather, they found evidence that sex role stereotypes were instrumental in influencing girls' choices of science courses and careers. They studied the effect of a female's perception of a field as 'masculine,' 'feminine,' or 'neutral' on her academic and career choices using subjects enrolled in coeducational public schools and in girls' schools, run by religious orders.

Girls in public schools selected subjects traditionally viewed as 'masculine' such as calculus, chemistry, and physics less often than males; and in spite of equal abilities, they performed less well than their male peers. Concommitantly, fewer indicated an interest in 'masculine' careers such as engineer, physicist, or mathematician. Other science areas traditionally are stereotyped as 'neutral;' these include most medical and the biological areas. Girls in coeducational schools enrolled and performed well in biology courses and indicated strong desires for careers in the life sciences.

In single sex schools, the differences noted above were not found. In an environment where they were not socially ostracized for success in a field perceived as 'masculine,' girls enrolled and achieved in physical science and in mathematics as well as in the natural sciences. In addition, they indicated interest in a range of scientific and technical careers.

Educational Factors

Bowyer, Linn & Stage (1980) report that the differences in male and female achievement scores on the two recent National Assessment surveys in science and mathematics are directly proportional to the number of semester hours taken in science and mathematics courses. For example, on the whole, females take one-third of a semester less mathematics and one-half of a semester less science than males; this fact alone may account for the achievement differences. As Fox (1980) explains, comparisons of mathematical ability between 17-year-old boys and girls are truly comparisons between students with 3-4 years of mathematics and those with 1-2 years of math. In a typical school district girls may outnumber boys in advanced eighth grade math classes, but by twelfth grade twice as many boys as girls are enrolled in calculus (Skolnick, et al., 1982). Many researchers think that the lack of courses in mathematics effectively eliminates most women from careers in the sciences (Iker, 1980; NSF, 1980; Boywer, in Trowbridge, et al., 1981). Fortunately, recent intervention programs have been successful; for the percentage of women who expect to take four years of high school math has risen from 37% to 57% in the last decade. The two point rise in SAT-M scores may be attributed to gains made by women. However, lack of training in mathematics may explain the findings that although females comprise over one-third of all students in higher education in England, they account for less than one of of every seven undergraduates in physics and for fewer than one in six in chemistry (Head, 1979). In this country, differences in number of mathematics courses may explain why twice as many college-bound senior boys as girls have had three years of physical science. Typically, a girl who wishes to pursue advanced science courses finds her fear that 'girls don't become scientists' reinforced clearly by the ratio of boys and girls in the classroom (Skolnick, et al., 1982, p. 40).

Differences in parent and in teacher expectations also affect the performance and enrollment patterns of women in science. Low parental expectation, evaluation, and encouragement may discourage girls from excelling in scientific areas (Graham, 1978; Kaminski, 1976; Fox, 1976). Bowyer states that boys in school are "valued for thinking logically, independently, with self-confidence, and an appropriate degree of risk taking." Girls, however, are "valued for their emotional expressiveness, sensitivity to others, dependency, and subjective thinking" (Bowyer, in Trowbridge, et al., 1981, p. 97). In elementary school and high school, girls and boys interested in science are treated differently by parents and teachers. "Girls found ambivalence, lack of encouragement, and messages that what they were doing was inappropriate, impractical, or unacceptable. Boys encountered much wider acceptance of their intentions as appropriate and admirable, particularly in terms of future economic status and a successful career" (Brown, Aldrich, & Hall, 1979, p. 1). As Skolnick, et al. (1982) explain, "While for boys math and science successes can heighten masculine self-esteem, girls must walk a tight rope between pride in their achievement on the one hand and a threat to their feminine self-image and social support on the other." (p. 42)

Most critically, however, both recent national surveys indicate inequities within science classrooms. Although achievement differences in science between boys and girls are not apparent until age 13, differential science experiences are documented as early as age 9. Briefly, by age 9, girls record significantly fewer opportunities to work with science materials and instruments, to observe natural phenomena, and to participate in extracurricular science activities.

In order to determine the reason for these disparities in science opportunities, a series of parallel questions was analyzed. For example, responses to items such as 'Have you used a balance?' and 'Would you like to use a balance?' were compared. Although many elementary school girls report wanting to observe natural phenomena such as watching a seed sprout or seeing the moon through a telescope the percentage of those who have done so is much lower. They also relate significantly fewer opportunities to use scientific instruments such as a meter stick, scale, telescope, microscope, compass, stopwatch, and balance, although they wish to use them. In addition, girls have fewer opportunities to participate in common laboratory experiences, although they express interest in doing such activities is equal to the interest expressed by boys. As a result, at age 17, or when they graduate from secondary school, girls have had significantly fewer opportunities to experiment with magnets, electricity, heat, solar energy, and erosion (NAEP, 1978b). Furthermore, there is a clear difference in girls' participation in traditionally feminine versus masculine tasks. Although secondary school girls respond far below the national averages concerning experiences with electrical or mechanical tasks, they respond above it in number of times they have cared for an unhealthy plant or animal.

A similar analysis of extracurricular science activities also reveals marked differences between males and females at ages 13 and 17. Secondary school girls participate less often than boys in all extracurricular science activities assessed. Females range from 1.3% to 7.6% below the national mean on activities such as watching TV science shows; reading books, magazines, and newspaper articles on science; and working with science projects or hobbies (NAEP, 1978b). In addition, although girls indicate an interest in taking a variety of science related field trips, fewer girls have opportunities to do so. This lack of extracurricular science experiences augments the overall deficiency in science for girls.

Personal Factors

A wide range of studies indicate that women are slightly more field dependent than men, and others suggest that more women score on the external end of the locus of control scale. However, research has indicated that these differences are not extreme enough to affect the entrance and success of women in science (Witkin, et al., 1977; Kahle, 1982). Another personal variable has been suggested. According to Maccoby & Jacklin (1974), the average score of a group of males is slightly higher than that of a group of females on tests measuring spatial visualization. Spatial visualization may be defined as the ability to manipulate an object or pattern in the imagination. Some researchers maintain that male spatial abilities are responsible for the higher achievement and interest levels boys express in math and science (Skolnick, et al., 1982). Treagust's reseach concerning infralogical groupings suggests that lower science achievement levels of 13 and 17-year-old girls are related to their slower development of spatial visualization. He maintains that lower spatial abilities of teen-age girls are due to slower developmental patterns rather than to the school curriculum which in the lower grades is largely the same for all students (Treagust, 1980).

However, two recent reports dispute his findings. First, Linn's (1982) meta-analysis of spatial ability research by gender reveals no significant differences between males and females before, during, or after puberty. In addition, the National Assessment data reported here indicate that girls and boys do not have equal experiences with science materials within science classrooms; such opportunities are critical in the development of spatial abilities. Fenneman & Sherman (1977) state that "covarying out the differences between the sexes in number of space related courses taken eliminates the sex-related differences in spatial visualization. This is consistent with the hypothesis that practice and relevant experience are factors in the difference between the sexes in spatial visualization" (p. 66). Skolnick, Langborg & Day (1983) maintain that experience with manipulative materials such as constructing and examining three-dimensional structures, graphing, and modeling are critical to the development of spatial visualization skills.

Implications

Although societal, educational, and personal factors have been identified which affect the science education of women, remedies are possible within the science classroom. The National Assessment data concerning girls' experiences with, activities in, and understanding of science indicate that different teaching strategies must be adapted from kindergarten through graduate school. For example, laboratory and demonstration activities which provide spatial experiences may enhance the spatial abilities of females. As Treagust (1980) points out, "A student with poorly developed spatial abilities should not be taught primarily by verbal means" (p. 95). Skolnick, et al. (1982) suggest a variety of science activities which range from recognizing similar shapes from different perspectives to converting two-dimensional patterns to three-dimensional objects and vice versa. In addition, girls must be encouraged to enroll in mechanical drawing, industrial education, and other courses which have activities designed to develop spatial abilities.

In science courses, laboratory groups must be carefully structured so that girls actually work with science apparatus. Teachers should encourage single sex pairs until girls hae gained the confidence and maturity to complete with boys, and they must recruit females to do science demonstrations.

Science teachers as well as school counselors and administrators must guard against unconscious bias in their presentation of science courses and careers or in their scheduling of science classes. For example, physics should not conflict with honors English, advanced French, or other courses traditionally selected by girls. The written and verbal use of non-sexist language in the classroom as well as in the text and other instructional materials is critical. Furthermore, the contributions of women must be portrayed seriously in narrative as well as illustrative materials. The inclusion of women photographed in lab coats is inadequate; their real contributions must be discussed. Research indicates that the sex-role stereotyping of science as a masculine endeavor is one of the most powerful deterrents to adolescent girls enrolling and excelling in science courses. If the repeated message from teacher and text is that scientists are males, adolescent girls, unsure of their femininity, will shy away from science or, if enrolled, perform poorly. The extent and strength of this masculine stereotype has been revealed by Chambers (1983) who received only 28 drawings of women from over 4800 students who particpated in the Draw-a-Scientist Test over an 11 year period. All of the female images were done by girls.

Recently, a nation-wide project analyzed factors affecting the retention of girls in science courses and careers (Kahle, 1983a). Collecting both observational and survey data, a team of researchers identified specific classroom climates, teacher behaviors, and instructional practices which were instrumental in encouraging girls in school to become women in science. These studies, conducted from rural Maine to urban California, from inner-city Illinois to suburban Missouri, from college preparatory Louisiana to agrarian Indiana, found the following commonalities among teachers who retained girls in science.

1. Whether the teacher taught behind locked doors in an out-of-date, traditional laboratory with bolted chairs and tables or in a modular, open-concept arrangement with flexible seating and stations, their classrooms were attractive, well-equipped and maintained. All noted that they did not need equipment and supplies or money for further purchases. In addition, all had adequate storage space.

2. All used non-sexist teacher-developed instructional materials to supplement the basic text. As one researcher noted,

> There is no overt discussion of sexism that might be inherent in any of the instructional materials used, as none of the materials seem to present that problem. Five tests were provided for analysis. There appeared to be no problem with sexist language; scientific contributions were treated as neutral relative to gender.

Interestingly, no observer reported a single use of sexist humor by the case study teachers.

3. All the observed teachers were aware of sexism in science. Although they maintained that they did not treat boys and girls differently, they brought women scientists into their classes and they included a range of non-sexist career information. As one observer suggested,

> Perhaps the equitable treatment of male and female students is itself special, given what has been learned about the generally inequitable treatment of female students in the science classroom. Perhaps the simple lack of preferential treatment for males has resulted in a situation where the female students feel comfortable and are confident in their ability to contribute at an equal level with their male collegues. Certainly, there is not enough data to support that hypothesis, attractive as it might be.

4. The teachers, perhaps unknowingly, presented what Harding (1983) and Smail (1983) call "girl friendly science." One observer wrote about this phenomenon in the following way.

> Although she argues that one does not need special activities to interest girls in science, it is possible that for the less-motivated girl certain labs and/or research projects are more appealing. For non-science-oriented girls, experiments such as audio-tutorial units on bacteriology have considerable appeal. Nutrition and diets appeal to many girls. A unit on 'Complementary Proteins: A simulation' has appealed to many girls. Similarly, 'Dissection of an Orange,' is very popular with many students. The teacher feels that the girls' interests are as varied as those of the boys. Last year a girl designed and built a windmill for a local garage and another girl spent hours assisting a vocational teacher who is building an airplane.

All of these, teachers used more laboratories, discusisons and tests than is commonly found.

5. The case study teachers all had solid, academic preparations for teaching. It should be noted that most had degrees in their subject areas and that all had continued their formal educations. All were more enthusiastic about teaching now than when they began to teach.

6. These teachers were respected, generally recognized, and supported within their communities. In addition, all but one mentioned that they received strong support from the parents of their students.

7. These teachers participate in and encourage their students to enjoy science beyond the schoolhouse door. As a result, one finds equal numbers of girls and boys preparing science projects and joining science, math, and computer clubs.

8. The case study teachers, individually and collectively, were unique in their emphasis on careers and further education. Although all students benefited from that interest, girls seemed to notice it and respond to it more than boys did.

9. According to their students, the instructional techniques of the case study teachers encouraged creativity, further education, and basic skill development. Again, girls noted these characteristics more often than boys did.

10. Both current and former students noted the positive attitudes as well as encouragement as unique personal characteristics and teaching behaviors of the case study teachers.

These ten special teaching behaviors and instructional strategies resulted in proportionately more girls in their classes continuing in math and science courses in both high school and college. Analyzing and comparing similar data demonstrate their effectiveness. Generally, the following behaviors characterize teachers who are successful in encouraging girls to pursue science.

Do	Don't
use laboratory & discussion activities	use sexist humor
provide career information	use sex-stereotyped examples
directly involve girls in science activities	distribute sexist classroom materials
provide informal academic counseling	allow boys to dominate discussion or activities
demonstrate unisex treatment in science classrooms	allow girls to passively resist

(Kahle, 1983b, pp. 30-32)

Across the country, girls, at least those in the case study classrooms, are beginning to question the old, masculine views of science and scientists. As two of them said,

> I don't know if it is women thinking scientists should be men, or men thinking scientists should be men.
>
> There are some women scientists; but men have been in it longer. Women can do the same job as men. They may have a different way of thinking and might improve science. (Kahle, 1983b, p. 25)

Changing attitudes about science and increasing experiences in science by direct and directed intervention will help more girls in school to beocme women in science.

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