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ABSTRACT

The direction and magnitude of sex-related differences in science attitude and achievement have been topics of conjecture and research. Reported here are findings of a quantitative synthesis of completed research relating to these issues. A comprehensive literature search revealed 83 "articles" (journal publications, books, unpublished reports, dissertations), standardized tests, and large-scale national/international studies providing data on sex differences and reporting either statistics from which "Effect Size" could be derived or information which could be tallied into "Vote Scores." (Vote scores contain less information than Effect Sizes, but their use permitted inclusion of all studies in which sex comparisons were made, even though detailed statistics were lacking.) Data from 298 independent samples provided 613 Effect Sizes and 132 Vote Scores which were analyzed using a general linear model approach to analysis of variance, controlling for intercorrelations among variables. Results indicated that sex differences in attitude/achievement were smaller than generally assumed, but when they did occur, with few exceptions, tended to favor males. Data on sex differences in attitude are discussed within the context of a large number of school, individual, and methodological variables including academic discipline, age, instrument reliability, country of sample, socioeconomic status, geographic region, age, and dimension of attitude. (Author/JN)

Sex-related Differences in Attitude Toward Science: A Quantitative Synthesis of Research

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Sex-Related Differences in Attitude Toward Science:

A Quantitative Synthesis of Research

Abstract

The direction and magnitude of sex-related differences in science attitude and achievement have been topics of conjecture and research for some time. Reported here are findings of a quantitative synthesis of completed research relating to these issues. A comprehensive literature search uncovered 83 "articles" (journal publications, books, unpublished reports, dissertations), standardized tests, and large-scale national and international studies which provided data on sex differences in science. These sources yielded a total of 613 standardized difference scores and 132 "vote" scores. Sex differences in attitude and achievement in science were found to be smaller than is generally assumed, but they do occur and, with few exceptions, they tend to favor males. Data on sex differences in attitude are discussed within the context of a large number of school, person, and methodological variables. A general linear model approach to analysis of variance which controls for intercorrelations among variables was used to analyze the data.

Introduction

That adult women are underrepresented in professional scientific communities is an undisputed fact (Astin, 1969; Cole, 1979). Concern with increasing the number of females in science professions continues to mount, however, as more and more Americans are primed to an awareness of existing conditions and as periods of national insecurity highlight the economic and humanitarian costs of inefficient use of female talent. Not surprisingly, it is assumed that the source of this differential representation is earlier achievement in school science. Yet those concerned with the teaching of school science are by no means in agreement concerning the size of differences attributable to sex; indeed many are uncertain whether differences do in fact exist. A review of research literature which provides a comparison of boys' and girls' performance on science-related measures--together with information on factors which contribute to sex differences--would facilitate the development of policy, theory, and classroom techniques more conducive to long-term achievement in science for females.

Earlier reviews have failed to maximize information which is available on sex differences. In the first place, search procedures have often lacked the systematic rigor necessary for a comprehensive examination of sex differences. For example, the typical library search uncovers only those reports whose titles and abstracts provide a clue that the gender issue was addressed in the study. The present project used more thorough search procedures in an attempt to locate any study or report in which the sample was described in terms of boys' and girls' performance on science-related measures. The inclusion of such studies not only increased the size of the data base but also provided a closer approximation to the natural setting since variables controlled or manipulated in the study were tailored to issues other than those associated with gender. Earlier efforts to accumulate information on sex differences in science have been narrow in another sense; they have tended to search only part of the available sources. The present study included not only refereed journal articles, chapters from books, dissertations, and Education Resources Information Center (ERIC) documents, but also included data from standardized testing procedures and large-scale national and international studies. Inclusion of reports which use varied samples and diverse testing conditions can provide more realistic overall estimates, and, when examined separately, can provide clues to specific conditions which precipitate sex differences. Earlier reviews--mostly narrative and subjective--have failed to provide quantitative information on the magnitude and nature of sex differences. Integrative techniques which are more powerful, sophisticated, and reliable than typical narrative reviews are needed if information for the improvement of school science is to be provided. The present project employs a "numbers and narrative" approach (Light & Pillemer, 1982) in an attempt to derive benefits of both qualitative and quantitative approaches to research synthesis.

Research and discussion on sex differences in the area of science often focus on achievement. This focus may stem in part from the fact that in the past a major goal of sex differences research has been to glean information on the etiology--genetic, psycho-social, or cultural--of women's disappointing performance record in science. The question, "Do boys do better than girls" has guided many investigations, but there is no clearcut answer; the answer will vary as a function of a large number of variables. A more desirable approach is to provide data on sex differences under diverse conditions and on as many of these variables for which information is available. Prime among the variables which determine achievement is attitude. A student's attitude toward science will determine his/her level of motivation, will play a role in directing the student's learning, and--most important--is probably one of the most crucial factors in the student's choice of courses and, later, a career. These issues guided our decision to conduct a two-pronged investigation with equal focus on attitude toward science and science achievement.

Taking all of these issues into account, three specific goals were formulated to guide the investigation. The first goal was to use meta-analytic techniques (Glass, 1976, 1978) to synthesize the research literature on sex-related differences in attitude and achievement in science and provide a quantitative estimate of the size and direction of the differences. A second goal was to examine and interpret information reported in the studies being synthesized concerning variables which might be related to sex differences. A third goal was to evaluate the scope and the quality of existing resarch in order to provide suggestions for conceptual and methodological refinements in future work.

Research on school-age children reported in the English language between the years of 1965 and 1981 was reviewed. The major unit analysis was the Effect Size (Glass, 1978); that is, the standardized difference between male and female scores $[(\overline{X}_M - \overline{X}_F)/\sigma]$ on objective measures of attitude and achievement. For those studies which compared male and female performances but failed to report statistics necessary for algebraic derivation of Effect Sizes, information on whether males or females received the higher score was tallied and called a "Vote Score" (Glass, 1976).

Method

Selection of the Data Set

The analysis used three samples of data. The first--called the "articles sample"--is composed of refereed journal articles, books, unpublished reports, and dissertations. To locate the "articles," computer searches of five library data bases were conducted: Psychological Abstracts (PSYC), Educational Resources Information Center (ERIC), Social Science Citation Index (SSCI), Comprehensive Dissertation Index (CDI), and Smithsonian Science Information (SMIE). Also, a comprehensive scanning of Tables of Contents and page-by-page scanning of books and journals was undertaken. All volumes of the two major journals in science education--*Journal of Research in Science Teaching* and *Science Education*--were scanned for the years 1965 through early 1981; all volumes of *Sex Roles* and *Psychology of Women* were scanned for the entire period of their publication; and all volumes of *School Science and Mathematics* (1969-1981) were individually examined. Also, the most recent five years of the following journals were examined: *Developmental Psychology*; *Journal of Psychology*; *Journal of Educational Psychology*; *Child Development*; *Human Development*; and *Child Psychiatry and Human Development*. Dissertation abstracts were located through listings in *International Dissertation Abstracts*.

Quality standards for inclusion in the synthesis. The traditional method of literature review has been criticized for its failure to respond differentially to varying quality-of-design features and analysis strategies (Cooper & Rosenthal, 1980). Most systematic discourses on the technique of meta-analysis address the topic of quality prerequisites for inclusion (Eysenck, 1978; Feldman, 1971; Glass, 1976; Jackson, 1980; Pillemer & Light, 1980), but no perfect solution to the problem has emerged. One approach would be to rate the quality of each study being considered and reject those failing to meet an a priori standard of methodological adequacy. Such a standard, however, would necessarily emerge as an arbitrary, subjective one, given the number of quality continua along which methodology might be evaluated and given the degree to which integrators vary in their perception of patterns of importance. The issue is rendered even more complicated by the fact that methodological inadequacies are not necessarily isomorphic with biased findings.

A more viable alternative is to use all available studies but to use them judiciously. This is the approach which was taken in this synthesis. Studies were evaluated critically (Campbell & Stanley, 1963), categorized with respect to factors such as sample size, reliability and validity of assessment measures, and method of sample selection. When relationships between design factors and outcome measures were found to occur, they were taken into account during interpretative phases of the project.

The literature search yielded 83 articles which reported either statistics from which Effect Size could be algebraically derived (Glass, 1976) or information which could be tallied into a "Vote Score." Vote Scores contain less information than Effect Sizes, but their use permits the inclusion of all studies which make sex comparisons even if detailed statistics are lacking. In effect, the use of Vote Scores--together with the inclusion in the project of unpublished reports as well as published ones--serves to control for the "file drawer problem" (Greenwald, 1975; Rosenthal, 1979). Briefly stated, the "file drawer problem" occurs when statistically significant results are published while less dramatic or loosely reported findings are "filed away" in desk drawers. The 83 articles picked up by the researh scan yielded 122 Effect Sizes and

and 74 Vote Scores for attitude and 107 Effect Sizes and 23 Vote Scores for achievement.

The second sample consisted of standardized test results. These were collected through contacts with test agencies and through perusal of the science section of Buros' (1974) Tests in Print. Additional test scores were culled from the 270 science test manuals maintained in the test file of the University of Illinois in Urbana-Champaign. The "Standardized Test Sample" produced three independent Effect Sizes for attitude and 70 independent Effect Sizes for achievement.

The third sample consisted of sex comparisons reported in national and international studies. The "large-scale sample" produced 82 Effect Sizes and 6 Vote Scores for attitude and 229 Effect Sizes and 29 Vote Scores for achievement.

Thus, the final study consisted of 613 Effect Sizes and 132 Vote Scores retrieved from 298 independent samples. Data from more than 14 million students across twenty countries of the world were entered into the analyses. A bibliography of articles, standardized tests, and large-scale studies--too lengthy for inclusion here--is available from the authors.

Coding

Variables that may influence sex differences were identified and incorporated into the coding scheme depicted in Table 1. Characteristics of the study, the sample, the school, and the instrument were numerically coded for each individual Effect Size and Vote Score. This listing of variables indicates the range of hypotheses which were tested with gathered information. Several variables, such as sex of examiner and certain methodological features (Campbell & Stanley, 1963) were deleted from the coding scheme because the information failed to appear in the studies reviewed.

A few of the variables in Table 1 require a word of explanation. "Quality of Journal" was coded according to criteria set forth by Koulack and Keselman (1975). In studies in which "Reliability Index" was not reported, the mean reliability for the subsample was used as a best estimate of reliability. This procedure ensured complete data sets necessary for the general linear model procedure to be used in the statistical analyses. It should be noted that complete information on many of the variables in the coding scheme was not available for standardized tests and most large-scale studies. It is because of truncated data sets (and gross differences in sample size) that these samples were analyzed separately.

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Insert Table 1 about here

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Studies were coded twice by the author, and differences--due to simple clerical error or increments in focus across time (Cooper, Note 1)--were resolved by checking the original document. Information from a random subset of ten studies was coded by a second rater in order to establish inter-coder reliability. On the coded variables there was 92% agreement. As predicted by Haring et al. (Note 2), most of the disagreement was on qualitatively defined variables while agreement on the quantitative variables--such as means and standard deviations--was almost perfect.

Computational Protocols

Either the male or the female sample standard deviation might have been used to standardize the sex difference scores in estimating the population Effect Size, since preliminary analyses on six subsamples of the data showed that the mean standard deviation for males and the mean standard deviation for females were essentially identical in each case. Because the standard deviation associated with the male scores was slightly less variable than was the standard deviation associated with the female scores in the present sample, the male standard deviation was used in the formula for calculating the Effect Size. An Effect Size estimator with smaller variance is preferred because the estimates obtained from it are presumed to be more consistent across samples. In order to control for bias in the distributions of Effect Sizes in the present study, a correction factor (Hedges, 1981) that utilizes sample sizes from both male and female groups was applied to each Effect Size.

In order to control for the occurrence of multiple scores from the same subjects, the Effect Sizes in the entire sample were weighted. In this synthesis, many studies contained multiple scores--say in chemistry, physics, and biology--from the same subjects. Other studies contained information for only one Effect Size. To simply tabulate all Effect Sizes would allow studies with many scores to weigh more heavily in the analyses, whereas averaging scores within each study would result in a loss of information. In order to control for this situation, a weight consisting of the reciprocal of the number of Effect Sizes in each independent sample was applied to each Effect Size. Sample rather than study was used as the independent unit because of the large number of studies which contained several independent age groups and independent countries. Thus, the procedure used here was to weight each independent sample equally, a procedure which satisfied the independence requirements of inferential procedures and also made it unnecessary to aggregate the findings above levels at which many interesting relationships can be studied.

A weighting to control for disparate sample sizes was not used in this synthesis partly because articles, standardized tests, and large-scale studies were being analyzed separately (there was minimal overlap in descriptive data associated with the three data sets), and this separation tends, by default, to group the data by sample size. A second reason was that to weight large-sample studies more heavily inadvertently results in heavier weighting for all variables coded in association with the larger samples. Furthermore, corr ‸cions between Effect Size and sample size confirmed a weak relationship ($\overline{r}_{xy}$ for all samples = -.19).

Statistical Procedures

A general linear model approach to analysis of variance (Tatsuoka, 1975) which controls for intercorrelations among variables was used to analyze the data. Attitude and achievement scores were considered separately for each of the three samples in the data set. In each case, the distribution of R^2 was dichotomized at the median and variables associated with larger R^2 values were entered into the analyses. A second stage of analyses resulted in the most parsimonious combinations of variables for explaining variance in attitude and achievement Effect Sizes. Follow-up analyses were then undertaken in order to describe patterns exhibited by those individual variables which, when viewed as a group, had been shown to contribute significant amounts of variance. As indicated earlier, all inferential procedures were based on Effect Sizes which were weighted to control for multiple scores from the same sample.

Results and Discussion

Table 2 shows means, standard deviations, and number of Effect Sizes for subsets of the data. All but one of the means are positive, indicating that when differences between the sexes occur, they tend to favor males.

Vote Scores, shown in parentheses in Table 2, tend also to favor males. It is clear, however, that despite the fact that sex differences tend to differ significantly from zero, sex differences in attitudes toward science, and levels of achievement in science are not large. (For purposes of interpretation, Cohen [1969] considers an Effect Size of .20 to be small, a value of .50 medium, and a value .80 large.) Not only do differences tend to be small, but male and female scores are highly correlated, with indexes for subsets of data ranging from .93 to .99 for attitude and .99 and .996 for achievement. Correlations of this magnitude suggest that, for all practical purposes, educational and social factors affect boys and girls equally.

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Insert Table 2 about here

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As shown in Table 2, the mean Effect Sizes for attitude are smaller than those for achievement. The largest mean Effect Size for attitude (.29) occurred in large-scale studies conducted in the United States. The two normal distributions schematized in Figure 1 depict a difference of this size and clarify the practical irrelevance of the difference. The large areas of overlap underscore the fact that girls' less positive attitudes toward science are too slight to provide grounds for limiting the life options of females. Clearly, mean differences in attitude toward science cannot be used as an explanation for females' underrepresentation in science professions or as a justification for their disappointing performance records in those fields.

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Insert Figure 1 about here

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The largest achievement Effect Sizes are found in the large-scale studies conducted in the United States (.48) and on standardized achievement tests (.43). One explanation for the larger mean Effect Size for standardized achievement tests relates to the manner in which students "select themselves" for the tests. Many talented high school boys are conceivably planning careers in science, take the tests, and do well on them. Many talented girls, on the other hand, undoubtedly choose not to take the tests (in the present sample 7,214,351 boys took the tests and only 6,996,702 girls) because they consider science interests inappropriate and socially deleterious for them.

This is not the first meta-analysis in which male-female differences in science-related outcomes are found to be small yet persistently in favor of males. Hyde (1981) applied quantitative techniques to Maccoby and Jacklin's (1974) review of studies examining quantitative ability, visual-spatial ability, and field articulation. Median Effect Sizes $(\overline{X}_m - \overline{X}_f)/\sigma$ were found to be .43, .45, and .51 respectively. These gender differences, however, were shown to account for no more than one to five percent of the population variance.

Table 2 provides insight into why pedagogically useful explanations of sex differences in attitude and achievement test scores in science are slow to evolve. While many of the differences are statistically significant, most of them are too small to provide specific implications for education. Moreover, when sex differences are trivial in size, statistical interactions between sex and relevant variables tend to be trivial as well.

Concentrating on differences in mean score oversimplifies the situation, however, not only because variability among individuals of the same sex is usually much larger than variability between the sexes, but also because the variability of male scores is usually larger than that of female scores. On achievement measures, for example, male scores are consistently more variable than females', even when mean differences are small or when differences favor females. The greater variability is associated with high frequencies at the lower and upper ends of the distribution of male scores (Humphreys, in press). High scores can be explained in part by an interaction between talent and optimal environment--an interaction often occurring in males but seldom occurring in females in whom talent is less frequently recognized and encouraged. The practical implications of this condition are discussed by Hyde (1981) who illustrates how relatively small mean differences can be associated with rather large differences in the proportions of subjects falling in the upper tail of the distribution. For example, given an Effect Size of .40, 7.35% of males and only 3.22% of females in the z-score distribution will fall above the 95th percentile cutoff sometimes applied in procedures for admittance to special programs of study. This phenomenon, together with the very pervasiveness of slightly higher scores for males, has the potential to legitimate stereotypic attitudes and behaviors. For example, upon learning or observing that there are more males in high scoring groups and that males' attitudes and achievement in science are more positive than females', parents, teachers, and counselors may set differing expectations for boys and for girls, unaware that the differences are too small to explain differences in career choice and success.

The three samples of data in this synthesis--articles, standardized tests, and large-scale studies--yielded extensive bodies of data on both attitude and achievement. Because of the large amount of information available on variables which impinge on attitude and achievement, only attitude data will be discussed here. Achievement will be discussed elsewhere (Steinkamp & Maehr, Note 3).

Before presenting positive findings of this synthesis, several negative findings deserve special mention. Although the three subsets of data shown in Table 2 showed patterns related to source of results, source of study within the articles sample did not significantly affect the size of sex differences. A number of meta-analyses report stronger findings for journal articles than for dissertations (Smith, 1980; Cohen, Kulik, & Kulik, 1982). The finding of no relationship in this review may be related to the fact that much of the sex difference data was gathered from studies in which the sex difference issue was examined only peripherally. This means that results of hypotheses relating to the main objective of the study--not sex differences--determined where the results were reported.

It is of interest that the subsamples in this synthesis provided no evidence that "Quality of Study" variables affected the magnitude of the Effect Size. Meta-analyses are frequently criticized for the inclusion of poorly designed studies and idiosyncratic sample selection (Eysenck, 1978; Rachman, 1971). Critics argue that the results of a few well-designed studies are more credible than those of many poorly executed ones. On the other hand, a number of meta-analyses report on design features which do not significantly influence results. For example, Smith, Glass, & Miller (1980), in a meta-analysis of the benefits of psychotherapy, report that inclusion of methodologically deficient studies did not affect the results. This finding held up in a secondary analysis of the same data (Landman & Dawes, 1982). Similarly, a quantitative synthesis of literature on the impact of leisure-time television on school learning (Williams, Haertel, Haretel, & Walberg, 1982) reported no relationship between design features of primary studies and synthesis results.

Variables Influencing Sex Differences in Attitude

Focus will shift from an exploration of the magnitude of sex differences in attitude to an examination of the origins of the differences, with a view to identifying ways of improving girls' attitudes toward science. What characteristics of the study, the sample, the school, and the instrument are related to sex differences in attitude toward science? Table 3 shows variables which--alone and in combination--made significant contributions to the variance in attitude Effect Sizes. There are 19 variables listed on the coding sheet (Table 1) which do not appear in Table 3. These variables were either redundant with the significant variables or did not make a significant contribution to the variance of the Effect Sizes. Breakdowns of the significant variables appear in Table 4 and will be discussed in the order in which they appear.

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Insert Tables 3 and 4 about here

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Throughout this discussion, relationships among Effect Sizes are examined closely in order to draw implications for theory and practice. A recurring question is, "Are large Effect Sizes caused by an increase in male scores or a decrease in female scores?" To answer this question for all significant variables in the study, distributions of male and female mean scores were plotted for visual comparison. None of the variables showed that larger Effect Sizes were a result of male or female scores being disproportionately inflated or depressed. This conclusion is confirmed by large positive correlations (quoted earlier) between male and female scores occurring throughout the project.

Dimension of Attitude. This variable accounts for significant portions of the Effect Size variance in both the articles and large-scale samples. As can be seen in Table 4, girls feel more strongly than boys that science is "not just for boys," but when asked about the relationship between themselves and science, girls respond more negatively than do boys. Also, girls are slightly less apt to express interest in science through "active involvement" with science-related extra-curricular activities. These findings supplement earlier speculations on the topic of sex differences in attitude toward science. For example, it has been proposed that many girls who like science consider science occupations too demanding to combine with family responsibility. Rossi (1965) and Seear (1964) suggest that females who might have chosen science careers fear hostility from male colleagues. Although many girls consider science appropriate for girls in general, they are less likely than boys to envisage themselves personally in science-based occupations (Butcher & Pont, 1968), possibly because of the paucity of female role models in those occupations (Walberg, 1969). Viewed together, these findings suggest that when asked outright, girls more than boys object to stereotypic labels for science subjects, but when it comes to identifying personally with science, engaging in science-related activities, or selecting careers in science, they continue to act in traditional ways. Girls' attitudes toward science appear to differ from their attitudes toward careers in science. The underrepresenation of females in science classes and programs of study (Benbow & Stanley, in press; Cole, 1979) confirms this interpretation.

Academic Discipline. The data provide evidence that sex differences in attitude toward science are larger in some subject areas than in others. As can be seen in Table 4, girls' attitudes toward biology, botany, and chemistry surpass those of boys while boys' attitudes are more positive than girls' in physical science and general science. Females' more positive attitudes toward biology and botany, which deal with life processes, may be related to their anticipation of a maternal role. Furthermore, since many high school girls enroll in courses dealing with life processes (Kelly, 1978), courses in those areas may have come to evolve around the verbal propensities of girls and thus serve as a vehicle for girls' increasing interest. Additionally, biology receives intensive focus in early elementary school, and girls may learn to like the subject before they and their classmates become cognizant of stereotypic labels.

In view of the physical science/biological science dichotomy sometimes used to describe subject areas within science, girls' more positive interest in chemistry, a physical science, was not anticipated. One reason why boys' attitudes toward this particular physical science were not more positive than girls' may be related to the fact that chemistry tends not to be learned and enjoyed informally outside the classroom. Physics and general science, on the other hand, can be learned outside the classroom, and boys have more opportunities to develop positive attitudes in those areas. Kelly (1978) reasons that sex differences in out-of-school learning can be estimated by examining sex differences among ten-year-old children, since few pupils have received much classroom instruction in science by ten years of age. She reports that differences were minimal in biology and chemistry, but pronounced in physics, which suggests that boys are exposed to far more physics than girls through out-of-school activities. Viewed in this way, the data in this synthesis indicate that girls' attitudes surpass boys' in those subjects such as biology, botany, and chemistry which are school-based, whereas boys' attitudes surpass girls' in those subjects which boys but not girls tend to learn informally through extra-curricular hobbies and contacts with knowledgeable males.

Cognitive superiority in males (Hyde, 1981; Maccoby & Jacklin, 1974; Tohidi, Note 4) is frequently proposed as an explanation for boys' more positive attitudes toward certain physical sciences. This argument is probably not a valid one, since girls' verbal superiority (Maccoby & Jacklin, 1974) should be even more conducive to the development of positive attitudes toward science, since verbal ability is more easily measured and rewarded than is cognitive ability--even in science classes. To some extent, these patterns of attitudes across science discipline supplement earlier work on course-taking. Comber and Keeves (1973) report that in ten countries for which data were available on courses taken by first-year college students, the proportion of women in physical science was lower than the proportion in biological science. Cole (1979) reports that in 1972, 18.4% of doctorates in biological sciences were awarded to women as opposed to only 4.4% of the doctorates in physical sciences. The pattern persists among academically exceptional students. Benbow and Stanley (in press) report that 20% of the females in their sample of precocious youth intended to major in biology as compared to 14% of the males. Of the males, 32% intended to major in physics and engineering, whereas only 15% of the females intended to do so.

Age. Although growth patterns cannot be inferred from the cross-sectional data in this review, male/female differences do vary as a function of age; sex differences in attitude toward science tend to decrease as age of sample increases. The significance of "age" in the general linear model analysis (Table 3) is confirmed by correlations between age and attitude Effect Size which were small and negative in the articles sample (-.26) and in the large-scale sample (-.15). A small, slightly negative relationship is predicted by work of Vestin (1975) who reported that children's attitudes toward sex roles in general become less stereotyped as they mature.

Type of Reliability. The "instrument" variables shown in Table 1 tend to be highly intercorrelated and all but "type of reliability" were eliminated from the general linear model. As shown in Table 4, girls' attitude scores were lower than boy's when reliability was determined by a second observer; that is, when a "visitor" was present. Several variables showed trends toward more negative attitudes in girls under conditions which provide a social component: girls report less positive attitudes than boys when the test is administered orally; they indicate less positive attitudes than boys when the test is individually administered; and they express less interest in science in small testing situations (correlations between sample size and attitude Effect Size were -.13 in the articles sample and -.09 in the large-scale studies sample.) These findings suggest that girls are reluctant to demonstrate positive attitudes toward science even if they experience them, possibly because they are aware that science has a masculine image. Cowan (1971) found that when asked to identify academic subjects suitable for boys and subjects suitable for girls, both sexes overwhelmingly placed science in the boys' category. Weinreich-Haste (1978), derived similar results using a semantic differential scale with older students. Thus, although girls believe in the abstract that science is for girls as well as for boys, in their own specific cases many fear that to show an interest may diminish others' views of their femininity.

Country of Sample. Variations in the magnitude of sex differences across countries are shown in Table 4. They lend indirect support for a cultural--as opposed to a genetic or psychosocial--explanation for sex differences in attitudes toward science. In the articles sample, girls' attitudes toward science surpass those of boys (-.12) in one country, Israel. The presence in that country of the kibbutz, where efforts are made to remove stereotypic labels from all tasks, appears to have a positive effect on girls' attitudes toward science. Preliminary evidence that the kibbutz has an equalizing effect is provided by Tamir (Note 5) who reports that kibbutz girls do better in science than do farm girls. In the articles sample, the largest mean Effect Sizes came from Australia/New Zealand (.37) and the United States (.10). When this pattern is compared with an index of the position of women in society reported by Torney, Oppenheim, and Farnen (1975), it can be seen that attitudes toward science may be a function of general attitudes toward women. Torney et al. found that in a sample of six countries--Finland, Germany, Italy, the Netherlands, New Zealand, and the United States--the proportions of 14-year olds who strongly agree with equal rights for women ranged from 17% to 52%. The United States and New Zealand had the lowest percentages (17% and 22%) of 14-year olds believing in equal rights for women.

Although cross-country variation was significant in the context of the set of variables contributing significantly to Effect Size variation in large-scale studies, it proved non-significant at the .05 level when examined alone. Table 4 shows strong trends, however, with the largest male/female differences occurring in Japan (.53). Japanese girls' less positive attitudes relative to boys' may serve as an explanation for Kelly's (1978) finding that of the countries for which data were available, Japan had the lowest percentage of female students enrolled in natural science at the tertiary level. In the present review, larger mean Effect Sizes also occurred in Sweden (.37) and the United States (.29). These patterns are surprising; sex differences were expected to be diminished in Sweden and the United States where conscious efforts are made to promote fair treatment of the sexes. Furthermore, these countries have a "mass"--as opposed to "elitest"--approach to education which should foster development of liberal modes of thinking. One would expect that countries making active attempts to remove inequity would be the first to manifest a diminution of sex differences in attitude toward science. As Rossi (1965) has suggested, however, social climate may be more important than social action.

It is of interest that relatively larger sex differences in attitude were found in technically developed countries (Australia, .37; Japan, .53; Sweden, .37; United States, .29) where according to some definitions, workers tend to be highly motivated to achieve (Maehr & Nicholls, 1980). This finding supplements that of Fyans, Salili, Maehr, & Desai (in press) who report that semantic concepts related to "femaleness" were related to science achievement in low-achievement-motivated cultures but not in high-achievement-motivated cultures. In some technically developed cultures, prejudices may be so deeply ingrained that they are taken for granted and pass unnoticed. Another explanation may relate to a tendency for parents in industrial societies to provide out-of-school science training for boys--but not girls--in order that they will be enabled to compete successfully in the more advanced society. As noted by Kelly (1978), "To them that have shall be given." (p. 113).

Viewed together, these cross-cultural findings suggest--at least for the short run--that sex differences are more apt to emerge in countries where sex differences are least expected: in countries which have been concerned with anti-discriminatory legislation, in countries implementing mass education, and in technically developed, achievement-motivated countries.

Sex differences appear least apt to emerge in countries providing more equitable home environments such as that afforded by the kibbutz.

Examination of sex differences in cultural subgroups may provide further enlightenment concerning the role of sociocultural phenomena in the production of sex-related differences.

Socioeconomic Status. Socioeonomic status belonged to the set of variables which contributed significantly to the variation in attitude Effect Sizes. Table 4 shows that girls' attitudes toward science are more positive in relation to boys' in disadvantaged communities while boys' attitudes toward science are more positive in upper middle-class communities. A possible interpretation is that stereotypic attitudes toward science tend not to be instilled in disadvantaged children who receive less attention from parents. Disadvantaged boys are not taught that science (or any academic discipline) is manly and most have not engaged in science-related hobbies with their fathers. Disadvantaged girls tend not to be taught to cultivate the motivational style (Steinkamp, in press) and ultra-feminine interests sometimes encouraged in middle- and upper-class girls whose parents are preparing them for success in the marriage market. These conditions would predict similar attitudes for boys and girls in disadvantaged communities, but females in some cultural groups achieve not only as well as males but, in many cases, at a higher level than do their male peers. This phenomenon has been reported for blacks and for Micronesians (Ballendorf, Note 6). One explanation may be that disadvantaged boys and boys in less well developed cultures have fewer experiences with child care, homemaking, and marketing than do girls and are thus less apt to have sampled the broad range of experiences which lay the cognitive groundwork for later interest and achievement in science. Moreover, in low socio-economic groups and in black and hispanic subcultures, school-related activities are specifically defined as feminine, and the father who expects the mother to handle all school matters provides for his son a role model which is indifferent toward school-related activities. The girl, on the other hand, learns how to be effective in the school setting.

In order to further examine the data for evidence that sex differences in science attitude are related to differing cultural environments, several subcultural groups within the United States which appear to provide different cultural experiences and expectations for boys and girls were examined separately.

Geographic Region. Though non-significant at the .05 level, a trend emerged when geographic region of the Untied States was examined for sex differences in attitude. Girls' attitudes relative to boys' were lower in the Midwest (ES = .31; N = 18) and slightly higher in the West (ES = -.03; N = 5). A frontier perspective may have played an important role in making the western states the first in the United States to grant suffrage, and although the reasons for granting suffrage were political rather than humanitarian, the ultimate effect on females may have been liberating. Similarly, the frontier perspective may have created a climate for the development of girls' interest in science. Young girls living in western states may, as a matter of lifestyle, engage in outdoor investigative activities conducive to later interest and achievement in science.

Age. When the age variable was categorized for analysis of variance procedures, it was found that sex differences were largest at the Junior High age level (.37), as shown in Table 5. The data provided no evidence that the larger Effect Size at the Junior High age range can be attributed to less reliable attitude measurement during those years in which students' attitudes typically undergo transformations.

Insert Table 5 about here

It is tempting to offer a biological explanation for increased sex differences at adolescence. Boys lag as much as two years behind girls in terms of physical development (Waber, 1977) and it would seem natural that attitudinal differences between males and females at these ages would be related to disparities in growth patterns and sexual awareness. If biological factors precipitate increased sex differences in attitude at adolescence, then a pattern of increased differences at adolescence should emerge in all cultures. That pattern did not appear in foreign samples in this review. Information from the Soviet Union was not available for this meta-analysis, but Dodge (1966) reports that efforts to promote the participation of adolescent females in science have been successful in that country. In the Soviet Union a uniform academic curriculum heavily weighted with science is taught to boys and girls alike. The scientist is often protrayed as a heroine in books and films and her work is glamorized and praised by the media (Dodge, 1966). The image of scientists fostered in the Soviet Union contrasts with the male image which is more common in the West (Hudson, 1968; Rossi, 1965; Selmes, 1969). If sex differences were somehow linked to biological factors, efforts to provide a positive image of female scientists, no matter how assiduously cultivated, could not be successful. A biological explanation for sex differences at adolescence is further weakened by reports of the dramatic efforts of simple discussion of stereotypic attitudes (Carey, 1958; Torrance, 1963) and the placing of "masculine" tasks within a feminine context.

Psychosocial facto s in the backgrounds of males and females provide a more adequate explanation for the increased sex differences at adolescence found in the United States. It has been shown, for example, that boys and girls manifest differential motivational patterns in the area of science and that although groundwork may be laid in earlier years, these are manifest at around age 13. At this age, girls' motivation shows a marked shift away from science (Haertel, Walberg, Junker, & Pascarella, 1981). Motivational factors, operating in concert with heightened sexual awareness associated with adolescence, produce boys and girls who are at pains to establish sexual roles which are exaggerated and traditional. A high priority among adolescent boys and girls, at least in this country, is to act thoroughly male or female. Girls who feel that achievement in science is not compatible with femininity (Lee & Gropper, 1974; Maccoby, 1970), are not free to focus on science interests. Furthermore, many females are less confident of their ability to perform on traditionally masculine pursuits and do not funciton well in competition with males on these tasks (Weinreich-Haste, 1978; Zuckerman & Wheeler, 1975). In the past, the occupational relevance of science lessions has been less for girls than for boys.

Sex differences in attitude at adolescence in the United States may be a function of changes in learning climate which occur when the student enters Junior High. The learning styles of girls which proved so successful in elementary grades may be less compatible with the requirements of Junior High science. Harding (1973), for example, proposes that girls function less well with the discovery approach often used in science classes. Teachers have reported that girls like to be directed and provided with continual feedback on their performance while boys are more apt to thrive in unstructured situations offered in high school. Ogunyemi (1972) reports that girls but not boys benefit from verbal information in discovery situations. These propensities place girls at a disadvantage in Junior High where discovery learning and independent learning styles play major roles. In many school systems, the first exposure to male teachers occurs in Junior High science classes.

Increased sex differences reported for the Junior High age group suggest that educators concerned with the problem of sex differences in science should focus on early adolescence. Many students may become interested in science later, but if their attitudes toward science are negative in the crucial adolescent years, science careers may no longer be an option for them (Sells, 1980). One approach would be to require a more rigorous sequence of science courses for girls during the years when gender intensification may cloud the picture of their aptitudes and interests. Given the cumulative nature of school science, efforts could be made during the junior high years to bring girls to the same starting point as boys who have had the benefits of incidental learning in science. Spatial skills could be taught in the Junior High school, in view of evidence that sex differences are more pronounced during early adolescence than in early years (Maccoby & Jacklin, 1974) and in view of evidence that spatial skills can, indeed, be taught (Conners, Schackman, & Serbin, 1978). Compensatory science for girls should fill the gaps not only in background knowledge but also in background attitudes. Another approach to remediation would involve changes in media to which teenagers are exposed. Adolescents are peculiarly vulnerable to widespread commercialism which pervades American culture. The mass media encourage in pubescent American girls an ideal which incorporates an indifference to phenomena traditionally labeled "masculine." Greater efforts must be made to remove stereotypic labels associated with science which are promulgated not only by the media but also by school texts (Weitzman & Rizzo, 1974) and, in some cases, the churches.

Complementary to the issue of removing the masculine image of science is the presenting of science in a way more appealing to the adolescent girl who is trying to be feminine. In addition to addressing questions of industrial, technical, and military importance, classroom science should place more stress on traditionally feminine interests such as health, food, children, and safety. Indeed, the exclusion of feminine, people-oriented topics constitutes a distortion and limitation of science and can result in the disproportionate recruitment into science of people who are interested in "things and ideas rather than people" (McClelland, 1961; Roe, 1951a, 1951b) and who express low interest in social activities (Helson, 1980). A more feminine science need not be less rigorous, of course; the concepts and theories would merely be packaged in a form more palatable to girls.

Year of Publication. When data from the United States were examined separately, a completely unexpected finding emerged; "Year of Publication" was found to bear a significant relationship to sex differences in attitude, with girls' attitudes becoming more negative in relation to boys' in the most recent six-year period. This tendency occurred both in the articles sample (Table 5) and in large-scale studies. To determine whether boys' attitudes were improving or whether girls' attitudes were deteriorating across time (Maehr, in press), the distributions of male means and female means were compared. It was concluded that although sex differences in attitude have become larger in recent years, both boys' and girls' attitudes are improving across time. When the correlation between male mean and year of publication ($r_{xy} = .24$) was compared with the correlation between female mean and year of publication ($r_{xy} = .11$) it became apparent that boys' attitudes were improving at a slightly greater rate. The data provide no evidence that the larger Effect Sizes in recent years are related to increasing reliability of attitude measurements. Examination of achievement data gathered in the larger study (Steinkamp & Maehr, Note 3) indicates that girls' achievement also deteriorated in relation to boys' in recent years.

That sex differences in attitude toward science are increasing rather than decreasing in recent years is a disturbing finding, particularly in light of recent efforts to remove stereotypic labels. Bias in text books and test materials has been documented (Weitzman & Rizzo, 1974) and called to the attention of teachers and administrators; programs have been instituted whereby role models have been provided for young girls; counselors and teachers (Harway & Astin, 1977) are increasingly being trained to counteract stereotypic thinking in both boys and girls; mothers are joining the workforce in large numbers and providing altered role models for their daughters. These efforts appear to have been successful in raising girls' consciousness, to have convinced them that science is "not just for boys" (as indicated earlier), but it appears that girls' attitudes toward science continue to be less positive than boys' and increasingly so in recent years.

Summary of Results

There were three purposes for this synthesis of the literature on sex differences in science. One was to determine the magnitude and direction of differences in school-age boys' and girls' attitudes and achievement in science. It was found that differences in favor of males did occur throughout the studies; while the differences were small, they were remarkably consistent for most subsamples of the data.

A second purpose was to examine in detail those variables which are suspected to be antecedents or correlates of sex-related differences. "Dimension of attitude" contributed significantly to the variance of attitudinal differences: girls strongly supported the notion that science is "not just for boys," whereas boys, more than girls, expressed positive attitudes toward science by engaging in science-related activities. Girls' attitudes were more positive than boys' in biological sciences and chemistry--subjects less apt to be encountered out of school--while boys' surpassed girls' in certain physical sciences--subjects which lend themselves to out-of-school learning. Males' attitudes were more positive in testing environments containing a social component--on individually administered tests, in situations in which responses were made orally, and on occasions where a second investigator was present. Among countries of the world, the greatest male superiority in attitude tended to occur in developed countries--especially Japan, Australia/New Zealand, Sweden, and the United States. In Israel, on the other hand, girls' attitudes toward science were found to be more positive than boys'. Males' attitude scores were higher in advantaged socioeconomic groups, with trends toward male superiority in the Midwest region of the United States. Boys' attitudes were more positive than girls' during Junior High years, but this pattern was manifest only in the United States. In the United States' articles sample, females' attitudes deteriorated significantly in relation to boys' in more recent years, a finding which mirrored a trend emerging in all subsamples of the United States' data.

The articles sample provided a broad range of variables which could be examined in association with Effect Sizes. Many of them either did not contribute significantly to the variance or were correlated with variables which contributed significant amounts of variance. Sixty-six percent of the variance in attitude Effect Sizes was explained by variables examined in this synthesis. If a larger percentage of the variance in sex-difference outcome measures is to be explained, then either (1) variables other than those encountered in the synthesized studies must be examined, or (2) the same variables must be examined with more rigor.

A third purpose of the study was to evaluate the scope and quality of research on sex-related differences in order to provide suggestions for future research. Contrary to expectations, an appalling lack of studies which responsibly address the issue of sex differences in science attitude and achievement was encountered; an unlimited reservoir of studies simply does not exist. With few exceptions, researchers are failing to address the gender issue in a straightforward manner. Even those studies which searched meticuously for differential effects of race, ability level, and type of instruction--important variables in the gender issue--tended to combine across categories and provide one gross sex difference comparison. Many studies failed to report minimal information for the calculation of Effect Size. Equally disturbing was the absence of theoretical threads pervading the literature. The anticipated "pockets" of literature addressing topics which impinge on sex differences failed to emerge. The quality of the studies which did address theoretical issues was particularly poor in terms of instrumentation and sampling: reliability and validity were cursorily ascertained; sampling procedures were inadequately explained. Throughout the studies there was a consistent failure to report data on which a judgment of methodology might be made.

Despite the statistical and conceptual weaknesses of many of the studies synthesized, several conclusions can be drawn with confidence. Sex differences in attitude and achievement in science are smaller than is generally assumed, but they do occur and, with few exceptions, they tend to favor males. Girls' attitudes are more positive than boys' in certain school-based subjects whereas the reverse is true in subjects which lend themselves--at least for boys--to out-of-school learning. In the United States' sample, males' attitudes surpassed females' during adolescence, and differences have increasel rather than decreased in the most recent years. Of greater concern, however, is the specific populations in which sex differences occurred. Contrary to expectation, sex differences appear to be no smaller in technologically advanced, achievement-motivated countries which foster mass education and equity legislation, and in advantaged socioeconomic groups. It would seem that those populations most capable of producing females with the ability, motivation, and extracurricular background for science--those populations which supposedly "know best" how to nurture scientific talent and have access to educational resources--are producing women whose attitudes leave them less well prepared for the competitive rigors of careers in science.

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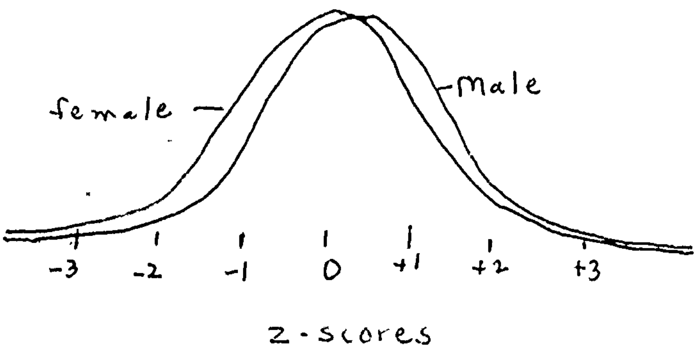

Figure 1. Two normal distributions representing an Effect Size of .29. This is approximately the magnitude of sex differences in attitude reported in the United States large-scale studies sample.

Table 1

Coding Information

Characteristics of Study
Year of publication
Source of reference
Quality of journal
Sample selection
Sample size
Characteristics of Sample
Country of sample
Region of country
Age
Ethnicity
Type of community
Achievement level
Socioeconomic status
Characteristics of School
Coed/separate
Instruction type
Regular class/project
Public/private
Characteristics of Instrument
Number of items in test
Type of reliability
Reliability index
Type of validity
Source of test
Individual/group administration
Stimulus mode
Response mode
Free/structured response
Dimension of attitude
Academic discipline

Table 2

Means and Standard Deviations of Unweighted Effect Sizes

	Attitude Toward Science			Achievement in Science		
	Mean Effect Size*	Standard Deviation	Number of Effect Sizes	Mean Effect Size*	Standard Deviation	Number of Effect Sizes
Articles						
United States	.10*(22,5,0)[1]	.42	74	.21*(11,0,0)	.38	93
Foreign	-.05 (31,16,0)	.50	48	.04 (4,8,0)	.20	14
Total Articles	.04 (53,21,0)	.46	122	.19*(15,8,0)	.36	107
Standardized Tests						
United States	.16[2]	.15	3	.43*	.13	70
Large-Scale Studies						
United States	.29*(3,0,3)	.32	14	.48*(20,0,1)	.33	28
Foreign	.23*	.27	68	.30*(6,1,1)	.29	201
Total Large-Scale Studies	.24*(3,0,3)	.27	82	.33*(26,1,2)	.30	229
GRAND TOTAL		Effect Sizes	207		Effect Sizes	406
		Vote Scores	80		Vote Scores	52

[1]Number of Vote Scores favoring males, females, and neither are shown in parentheses

[2].95 Confidence Interval not calculated because of small number of Effect Sizes

*.95 Confidence Interval did not contain zero

Table 3

Analysis of Variance on Weighted Effect Size (Attitude)

(Multiple Independent Variables)

Articles	SS[1]	PR < F	Standardized Tests	Large-Scale Studies	SS[1]	PR < F
Dimension of Attitude	0.97	0.00	Only three standardized	Dimension of Attitude	0.53	0.00
Academic Discipline	1.69	0.00	attitude tests	Age	0.00	0.57
Age	0.51	0.00		Country	0.15	0.00
Type of Reliability	0.25	0.05		Coed/Separate	0.00	0.31
Country	0.36	0.01		Sample Size	0.00	0.91
SES	0.56	0.00				
Type of Validity	0.19	0.11				
Reg Science/Curr Project	0.10	0.19				
SS Model 5.47				SS Model 1.41		
$F = 6.91$ $df = 26,119$ $p < 0.001$ $R^2 = .66$				$F = 20.54$ $df = 19,81$ $p < 0.001$ $R^2 = .86$		

[1]SS value takes into account the presence of all variables in the model

Table 4

Statistics on Individual Variables

(Attitude)

	Mean Effect Size	Number of Effect Sizes
Dimension of Attitude (Total Articles)		
Science important	.13	13
Enjoy science	.04	54
Science and self	.21	12
Not just for boys	-.61	10
Active involvement	.12	9
General	.17	22
F = 2.54 df = 5,119 p < .03 (weighted data)		
Dimension of Attitude (Large-Scale Studies)		
Science important	-.05	20
Enjoy science	.35	20
Science and self	.16	20
Active involvement	.54	20
General	-.03	4
F = 39.71 df = 4,81 p < .0001 (weighted data)		
Academic Discipline (Total Articles)		
Biology	-.28	9
Chemistry	-.31	9
Physics	-.01	23
General Science	.20	58
Physical Science	.35	4
Geology	.14	5
Botany	-.60	5
Zoology	-.60	7
F = 6.33 df = 7,119 p < .0001 (weighted data)		
Type of Reliability (Total Articles)		
Not discussed	.01	51
Kuder-Richardson	-.01	52
Test-Retest	.03	11
Interobserver	.81	6
F = 6.97 df = 3,119 p < .001 (weighted data)		

Table 4 (continued)

	Mean Effect Size	Number of Effect Sizes
Country (Total Articles)		
Australia	.37	5
England	.02	6
United States	.10	72
Israel	-.12	37
$F = 3.64$ $df = 3,119$ $p < .01$ (weighted data)		
Country (Large-Scale Studies)		
Australia	.23	8
Belgium Fl	.00	4
Belgium Fr	.01	4
England	.26	16
Germany	.29	4
Finland	.17	4
Hungary	.06	4
Italy	.18	4
Japan	.53	4
Netherlands	.29	4
Scotland	.25	4
Sweden	.37	8
United States	.29	14
$F = 1.20$ $df = 12,81$ $p < .30$ (weighted data)		
Socioeconomic Status (Total Articles)		
Disadvantaged	-.22	3
Upper-middle	.67	10
Mixed	-.01	107
$F = 16.96$ $df = 2,119$ $p < .001$ (weighted data)		

Table 5

Patterns of Sex Differences in Attitude

Within the United States Sample

	Mean Effect Size	Number of Effect Sizes
Age (U.S. Articles)		
Less than 11 years	.13	21
12-14 years	.37	15
15-17 years	.01	28
18 years and older	-.13	8
$F = 3.51$ $df = 3,71$ $p < .02$ (weighted data)		
Year of Publication (U.S. Articles)		
1965-1969	.02	41
1970-1974	.05	15
1975-1981	.36	16
$F = 2.83$ $df = 2,71$ $p < .066$ (weighted data)		