Review of Educational Research
Fall 1983, Vol. 53, No. 3, Pp. 369–396

Affect, Ability, and Science Achievement: A Quantitative Synthesis of Correlational Research

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Abstract. In a comprehensive review of the literature containing correlations among affect, ability, and achievement in science—and between each of these variables and gender—findings were synthesized quantitatively with a view to determining the size and direction of relationships as well as the degree to which the relationships were modified by gender, level in school, and content area within science. Retrieved from 66 articles and reports, the data base consisted of 255 correlations. We found that boys' and girls' science achievement is positively related to affect, but the relationship is weaker than was expected; science achievement correlates more strongly with cognitive abilities than with affect. In both boys and girls, affect is more strongly related to achievement level than to cognitive abilities. The data suggest that boys achieve slightly better than girls in science, and they tend to possess slightly more cognitive ability. In some content areas within science, boys demonstrate more positive affect than do girls; in other content areas the reverse is true.

An ongoing argument in educational circles concerns whether one should stress the development of proficiency in the hope that motivation will follow or stress the development of positive feelings in the hope that this will encourage the development of proficiency. This argument takes on a special form in the case of observed male/female differences in science achievement. There is little question that women have not achieved in the area of science to the same degree men have (cf., e.g., Steinkamp & Maehr, in press). A major cause is thought to be attitudinal: Females simply do not *like* science as well. The implication of this conclusion is that science instruction ought to focus especially on affective outcomes. Before fixing on this plan of action, however, we do well to examine the research literature on the cognitive and attitudinal origins of science achievement, focusing particularly on gender differences, which is our intent in this paper. Unfortunately, the research literature concerned with attitude, ability, and achievement relationships does not speak with one voice. The studies on the topic are many but the actual findings are inconsistent, even contradictory (Brodie, 1964; Diedrich, 1966; Finger & Schlesser,

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A number of people were helpful at various stages of this research. In particular we are indebted to Harris Cooper, John A. Easley, Herbert J. Walberg, and Barbara K. Kremer.

The research on which this paper is based was supported by NSF-RISE Grant No. 80-07857, Martin L. Maehr, Principal Investigator.

1968; Goldfried & D'Zurilla, 1973; Husen, Fagerlind, & Liljefors, 1974; Jackson & Lahaderne, 1967; Kahn, 1969; Keeves, 1972, 1973; Malpass, 1953; McBee & Duke, 1960; Williams, 1970). Moreover, it should be emphasized that the picture is often further confused when one considers male-female differences in science achievement.

Obviously, then, the research literature cannot readily yield clear answers if the usual procedure of literature review and synthesis is pursued. Therefore, we have chosen to use a promising alternative: meta-analysis (Glass, 1978). Presented here is a quantitative synthesis of studies reporting correlations among ability, affect, and achievement—all within the specific field of school science where the relationships between the variables and motivation are thought to be important but not at all well understood (cf. Maehr, in press; Steinkamp, in press). The review is further limited to studies that consider gender differences in the area of science. How do boys and girls feel about science? Do these feelings possibly stem from differential ability? How important are they in determining achievement?

Procedure

Quantitative synthesis is a relatively new technique composed of a variety of statistical methods for summarizing and evaluating a series of empirical findings across investigations (Cooper & Rosenthal, 1980; Glass, 1978; Light & Smith, 1971). The procedure is an outgrowth of the increasing concern over how well we can understand large bodies of research reported in the literature. With the vast amount of research accruing in the area of science education, it has become more and more difficult to conduct reviews of the literature with any semblance of rigor. Gross application of nonparametric statistics to a few broad categories no longer suffices (Presby, 1978), and attempts to integrate studies narratively are recognized as potentially misleading.

In its broadest sense, the goal of quantitative synthesis is a summary of findings of studies already completed, which will generate hypotheses for future research. A particular advantage of quantitative synthesis is that it can reverse erroneous impressions sometimes formed on the basis of a few well-executed, memorable studies that may not be a valid reflection of extant research.

Literature Search and Selection

The present study was conducted in conjunction with a larger effort funded by the National Science Foundation. In undertaking the larger project, a comprehensive search of the literature was conducted to locate studies containing mean and standard deviation scores for males and females on science-related test measures. For the present study, the same body of research was examined, but only those studies containing correlations—or statistical values from which correlations could be calculated (Glass, 1978)—were screened for analysis. Criteria for inclusion in the present study were the following:

(1) the study involved students in pre-school through early college;
(2) the study was conducted on English-speaking children;
(3) the study appeared in the literature between 1965 and the present;
(4) a. the study reported correlations between gender and science achievement, gender and cognitive ability, or gender and science-related affect; or

b. the study contained separate correlations for the two sexes between science achievement and cognitive ability, science achievement and science-related affect, or science-related affect and cognitive ability.

It was necessary that the selection process be guided by carefully elaborated definitions of achievement, cognitive ability, and affect. For purposes of this paper, *achievement* was measured by paper-and-pencil, factually oriented instruments, either teacher-made or published, which attempted to ascertain the child's knowledge and comprehension of science (Bloom, 1956). Examples include the *Test of Environmental Information*, the *Science Test* prepared for the Australian Capital Territory, and a teacher-made test of factual knowledge about electrostatics.

Cognitive ability was defined by phenomena typically measured with mechanical or pictorial devices that present problems to be solved through analysis, synthesis, and evaluation (Bloom, 1956). The items in the cognitive ability tests measured, for example, concepts, principles, and creativity, usually within the broad area of science rather than within specific substantive areas. Examples of instruments used to measure cognitive ability include the *Science Process Inventory*, a *Test of Scientific and Logical Thinking*, and Inhelder and Piaget's (1958) chemical and electronic tasks. In six cases it was necessary to consult the test manual or examine individual items in categorizing the instruments with respect to definitions of achievement and cognitive ability that guided the present investigation.

Affect was defined by instruments purporting to measure emotions, values, and feelings related to science. A study was not included in the synthesis unless it measured affect specific to the science domain under consideration. Thus, "attitude toward school" fell outside the scope of the study, while measures of attitudes toward physics, self-concept of ability in science, and chemistry attitude were appropriate for inclusion in the synthesis.

A tabulation and description of tests categorized under the rubrics of achievement, cognitive ability, and affect can be seen in Table I.

As an initial step in the literature search, computer scans of four library data bases were conducted: Psychological Abstracts (PSYC), Educational Resources Information Center (ERIC), Social Science Citation Index (SSCI), and Comprehensive Dissertation Index (CDI).

A comprehensive scanning of tables of contents (and page-by-page scanning, because the title and abstract could not be counted on to indicate whether or not data were reported separately by sex) 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 entire period of their publication; and all volumes of *School Science and Mathematics* (1969–1981) were individually examined. Also, the most recent 5 years of the following journals were examined: *Developmental Psychology*, the *Journal of Psychology*, *Journal of Educational Psychology*, *Child Development*, *Human Development*, and *Child Psychiatry and Human Development*. Dissertation abstracts were located through listings in the *International Dissertation Abstracts*. Especially fruitful for our purposes was examination of studies quoted in the text or appearing in bibliographies of selected studies.

The comprehensive search yielded 66 studies that were considered appropriate for this synthesis. They provided a total of 255 correlations—either direct or

TABLE I

Descriptive Information on Studies Included in The Synthesis

Investigator	Sample size	r_{xy}[a]	Description of subjects	Disciplinary focus within science	Instruments	Reliability
			Gender/Achievement			
Doran & Sellers (1978)	320	+.11	Grade 10 biology students	Biology	Nelson Biology Test	.90
Keeves (1975)	215	+.18 +.16	Final elementary year, Australia	Science	Science Achievement Test (Australian Capital Territory)	
Raven & Adrian (1978)	9th grade 113	+.23	High school biology students, average or above	Science	Sequential Test of Educational Progress (STEP) Science	.87
	10th grade 75	+.16		Science	STEP Science	.84
	11th grade 61	+.13		Science	STEP Science	.86
Marek (1981)	37, 55	+.09	Midwest, grades 9, 10	Biology	Test questions from Biological Science Curriculum Study	.73
Sieveking & Savitsky (1969)	707	−.06	University freshmen	Chemistry	Am. Chem. Soc. Test	.92
	707	−.02			Chemistry classroom grade	
Hart (1978)	300	+.06	Grade 12, Canada	Ecology	Test of Ecol. Comprehension	.67
		+.27	Grade 12, Canada	Environment	Test of Envir. Information	.41
Lynch et al. (1979)	969, 666	+.11	Ages 12–16, Tasmania	Chemistry concept words	Definitions of concept words in chemistry	.71
Wallach & Kogan (1966)	70, 81	−.02	Grade 5 middle SES	Science	STEP Science	.91
Walberg (1969)	675, 375	+.24	National sample, high school physics students (also Canada)	Physics	Physics Achievement Test, locally constructed	.77
Thomas & Snider (1969)	65, 65	+.65	Grade 8, Midwest	Science, geology, archeology	Teacher-made	.85
Bridgham (1969)	29, 21	+.26	Grade 3, Massachusetts	Electrostatics	Specially designed	
Skinner (1968)	458, 430	.00	Grade 5, suburban	Geology	Constructed by investigator	
Babikian (1971)	108, 108	+.25	Grade 8, science classes	Science	Constructed by investigator	

Investigator	Sample size	r_{xy}[a]	Description of subjects	Disciplinary focus within science	Instruments	Reliability
			Gender/Cognitive ability			
Doran & Sellers (1978)	320	+.04	Caucasian, 10th grade biology	Science process	Test of Science Process	.91
Doran (1972)	253	−.003	Grades 2–6, Midwest, mid SES	Chemistry	Constructed by investigator	.60
Marek (1981)	37, 55	−.05 +.25	Grades 9, 10, biology students, Midwest	Biology Biology	Explanations in Biology from Inhelder & Piaget	.80
Lowell (1980)	60, 60	+.04 −.32	Ages 6–16, Newfoundland	General science	Piagetian tasks in science context, Hierarchical class	
Bredderman (1974)	240	+.12 +.03 +.06 +.06 +.06 +.06	Grades 4, 6, 8, 10 in various science programs	General science	Constructed by investigator Number of men constructed Combinatorial, Variables Controlled, Logical Necessity, Nonlogical Necessity	
Field & Cropley (1969)	104, 74	−.003	Ages 16–18, science students, country high schools	General science	Understanding in Science Questionnaire	
Ashbaugh (1968)	41, 41	+.35	Grade 4, Georgia, suburban	Geological concepts	Constructed by investigator	.84
	32, 32	+.02	Grade 5, Georgia, suburban	Geological concepts	Constructed by investigator	
	39, 30	+.26	Grade 6, Georgia, suburban	Geological concepts	Constructed by investigator	
Wallach & Kogan (1966)	70, 81	+.47	Grade 5, middle SES	General science	Creativity Tests	.51
		+.22				.75
		+.04				.87
		+.04				.93
		+.02				.87
		−.00				.93
		+.04				.88
		−.03				.93
		+.001				.82
		−.10				.93
Rowell (1971)	116, 118	+.26	Year 3, top stream, Australia	General science	Test of Scientific and Logical Thinking, prepared by investigator	

TABLE I—*Continued*

Investigator	Sample size	r_{xy}[a]	Description of subjects	Disciplinary focus within science	Instruments	Reliability
Tamir & Kempa (1978)	110, 111	+.21	Grade 10, Israel	Physics	Cognitive Preference Test	.81
		−.18	Grade 10, Israel	Chemistry	Cognitive Preference Test	
Walberg (1969)	675, 375	−.12	High school physics students, 17 states, 2 Canadian provinces	Science	Science Process Inventory	.76
		−.11			Test on Understanding Science	.86
Thomas & Snider (1969)	65, 65	+.06	Grade 8	Science	Inventory of Science Process	
		−.20	Grade 8		Watson-Glaser Critical Thinking	
Tamir & Amir (1975)	64, 51	+.23	Grades 1, 2, Israel	Science	Practical Science Test	
		+.22			Prepared by investigator	
		+.27				
		+.38				
		+.10				
		+.07				
Babikian (1971)	108, 108	0	Grade 8 science classes		Verbalization Concepts	.76
		+.22			Recognition of Concepts	
		+.27			Cognitive Transfer	
		+.02			Cognitive Problem Solving	
Allen (1972)	106, 106	+.17	Grade 2, Honolulu	Chemistry	Cognitive Performance	
Allen (1973)	100, 76	+.02	Grade 3	Chemistry	Science Curriculum Improvement Study Curriculum Test	
Bowyer & Linn (1978)	284, 247	−.11	Grade 6, rural Michigan		Scientific Literacy Test	.92
Pettus & Haley (1980)	283, 222	−.22	Grades 9–12, Conservation camp		Test of Science Processes	.78
Smith & Schroeder (1979)	36, 42	+.11	Grade 4, Midwest, mid SES		Spatial Visualization Abilities Test	
Saarni (1973)	32, 32	−.36	Grades 6, 7, 8, 9		Rod and Frame	
Goldschmid (1967)	38, 43	+.28	Grades 1, 2, urban		Piagetian Tasks	
Linn & Levine (1978)	60, 60	+.25	Ages 12, 14, 16, London		Circuit and Ramp	
Maxwell, Croake, & Biddle (1975)	18, 17	+.56	Age 9		Spatial Orientation	
Robertson & Richardson (1975)	100, 100	+.05	Grades 7, 8, 9, 10, Australia		Volume, Force, Acceleration	

Investigator	Sample size	r_{xy}[a]	Description of subjects	Disciplinary focus within science	Instruments	Reliability
Douglas & Wong (1977)	60, 60	+.30	Age 14, American Chinese		Piagetian tasks	
Dale (1970)	100, 100	+.19	Ages 6–15, Australia	Chemistry	Chemical Experiment (Piaget)	
Lawson (1975)	31, 31	+.21 +.36	Age 15, Indiana, biology students		Bending, Balance, Proportions	
DeLuca (1977)	28, 27	+.05	Grade 12, chemistry students	Chemistry	Piaget, chemical/electronic	
Jahoda (1980)	80, 80	+.39	Ages 12–16, Scotland, Ghana		3D Mental Rotation	
Ryman (1977)	48, 48	+.21	Age 12, England		Classification Task	
Treagust (1980)	54, 54	+.32	Age 16		Spatial Thought	
Nelson (1976)	50, 50	−.26	Ages 3–5		Concept Development	
DeLuca (1979)	198, 186	+.02	Grades 4–12		Piaget Chemical Experiment	
Za'Rour (1971)	377	+.26	Grades 2–4, Lebanon		Conservation of Weight	
Piburn (1977)	30, 36	+.34	Junior high through college		Piagetian Tasks	
Za'Rour & Panaouri-Kilaniotis (1977)	45, 45	+.29	Grades 2, 3, 4, Lebanon		Categorization/Conservation	
Liben (1978)	33, 33	+.33	Grade 12, white, suburban		Piagetian Horizontal/Vertical	
Jahoda (1979)	72, 72	+.34	Grades 2–7, Ghana, Scotland		Block Construction	
Keogh (1971)	75, 60	+.25	Age 9, suburban California		Walked Patterns	
			Gender/Affect			
Doran & Sellers (1978)	320	+.04	Grade 10, Caucasian		Self-concept in Science	.55
Keeves (1975)	215	−.25	Age 11, Australia		Attitude Toward Science	
		+.24	Age 11, Australia		Attitude Toward Science	
Raven & Adrian (1978)	249	+.04	Grades 9, 10, 11		Self-concept of Science Ability	
Hart (1978)	300	−.06	Grade 12, Saskatchewan		Attitudes Toward Environment	.97
Meyer (1970)	1,236	+.22 +.22 +.39 +.02	Age 16, British high school		Attitudes Toward Science	

TABLE I—*Continued*

Investigator	Sample size	r_{xy}^{a}	Description of subjects	Disciplinary focus within science	Instruments	Reliability
Power (1981)	1,158	+41 −.26 +.29 +.08 +.02 +.05 +.21 +.02 −.17 −.01 +.23 +.16 +.28	Grade 7, Australia	General science	Science-related Attitudes	.69
Fraser (1978)	132,170	+.48 .40 .21 .11	Grade 9, Australia	General science	Enjoy, Interest, Fluidity, Social	.87 .85 .65 .74
Peterson, Kauchak, & Yaakobi (1980)	115, 105	−.08	Grades 7–12	General science	Science Self-concept, Q Sort	
Haladyna & Thomas (1977)	941, 901	+.15 +.26	Intermediate grades	General science	Attitude (Me, What I Like Best)	.61 .89
Tamir, Arzi, & Zloto (1974)	82, 75	+.52 +.30 +.36 −.37 −.30 −.60 −.56	Grades 11, 12, Jerusalem	Physics	Physics Attitude Scale	.74 .86
Hofstein, Ben-Zvi, Samuel, & Tamir (1977)	140, 160	−.22 +.01	Grades 11, 12, United States, Israel	Chemistry	Chemistry Attitude Scale	.74

Inves-tigator	Sample size	r_{xy}[a]	Description of subjects	Disciplinary focus within science	Instruments	Reliability
		−.52				
		−.26				
		−.55				
		−.59				
		−.34				
Walberg (1969)	285, 565	+.00	High school, United States, Canada	Physics	Semantic Differential	.73
		−.04				
		+.14				
		+.07				
		−.19				
		−.08				
		−.06				
		+.15				
		−.18				
		+.00				
		+.16				
		+.08				
		+.05				
Walberg (1967)	725, 332	−.12	Grade 12, United States, Canada	Physics	Reed Science Inventory	.97
		−.40				
		+.78				
		+.09				
		−.35				
Lowery, Bowyer, & Padilla (1980)	54, 56	+.44	Age 12, suburban		Projective Test of Attitudes	.91
		+.30				
		+.73				
Hofman (1977)	40, 39	−.19	Age 8, low SES		Projective Test of Attitudes	
Carnes, Bledsoe, VanDeventer (1967)	221	+.30	Grade 7		Kuder Science Interest	

TABLE I—*Continued*

Investigator	Sample size	r_{xy}[a]		Description of subjects	Disciplinary focus within science	Instruments	Reliability
Lazarowitz & Lazarowitz (1979)	575, 371	−.13		Grades 7, 8, 9, Israel		Preferences	.83
		−.16					
		−.16					
		−.09					
		−.07					
		−.12					
		+.21					
		+.15					
		+.19					
		+.13					
		+.12					
Allen (1972)	106, 106	+.11		Grade 2, Honolulu		Chemistry Affect	
Power (1981)	343	+.18		Grade 7, Australia		Semantic Differential	.89
				Achievement/Cognitive ability			
		Boys	Girls				
Marjoribanks (1978)	219, 210	+.74	+.70	Grade 7, England	Biology	Biol ach/verbal reasonining	.96
		+.57	+.66		Biology	Biol ach/nonverbal reasoning	.95
		+.51	+.47		Biology	Biol ach/divergent ability	
		+.71	+.67		Physical science	Phys Sci ach/verbal reasoning	.94, .96
		+.51	+.66		Physical science	Phys Sci ach/nonverbal reasoning	.94, .95
		+.39	+.42		Physical science	Phys Sci ach/divergent ability	.94
Marjoribanks (1976)	195, 201	+.39	+.41	Grade 7, England	Physical science	Phys Sci Ach/creativity	.94
		+.51	+.45		Physical science	Biol Sci Ach/creativity	.93
Wallach & Kogan (1966)	70, 81	+.34	+.34	Grade 5, mid SES	General science	STEP Sci/Block Design	
Bridgham (1969)	29, 21	+.12	+.41	Grade 3	Physics	Electrostatics/classification	
		+.36	+.36		Physics	Electrostatics/seriation	
		+.47	+.32		Physics	Electrostatics/additive classification	
Cline, Richards, & Needham (1963)	74, 40	+.39	+.31	High school students, two courses beyond general science	General science	STEP Sci/Hidden Figures	
		+.03	+.03			STEP Sci/Immediate Consequences	
		+.43	+.21			STEP Sci/Consequences Remote	

Investigator	Sample size	r_{xy}[a]		Description of subjects	Disciplinary focus within science	Instruments	Reliability
		+.13	−.14			STEP Sci/Brick Uses	
		+.46	+.03			STEP Sci/Brick Uses Change	
		+.36	+.20			STEP Sci/Match Problems	
		+.47	+.31			Sci gr/Hidden Figures	
		+.02	+.30			Sci gr/Consequences Immediate	
		+.35	+.11			Sci gr/Consequences Remote	
		+.24	+.19			Sci gr/Brick Uses	
		+.34	+.32			Sci gr/Brick Uses Change	
		+.47	+.38			Sci gr/Match Problems	
		+.36	+.40			Sci Rating/Hidden Figures	
		+.04	+.21			Sci Rating/Consequences Immediate	
		+.24	+.17			Sci Rating/Consequences Remote	
		+.29	+.24			Sci Rating/Brick Uses	
		+.31	+.06			Sci Rating/Brick Uses Change	
		+.35	+.43			Sci Rating/Match Problems	
				Achievement/Affect			
		Boys	Girls				
Schock (1973)	206, 177	+.28	+.20	28 biology classes in midwestern high school	Biology Ach/ASLT	Nelson Biology Test	.89
		+.22	+.27			A Scientific Literacy Test	
		+.03	+.03				
Cline et al. (1963)	74, 40	+.38	+.35	High school students having completed two science courses beyond general science	General science	STEP science/involvement with science	
		+.18	+.07			STEP science/number of science courses	
Welch (1969)	125, 82	+.02	+.33	Physics students enrolled in Harvard Project Physics	Physics	Physics Achievement Test PAT/ Course Satisfaction Scale of Project Physics Student Questionnaire	.77 .80
		+.28	+.35			Course Grade/Course Satisfaction Scale of Project Physics Student Questionnaire	.80

TABLE I—*Continued*

Investigator	Sample size	r_{xy}[a]		Description of subjects	Disciplinary focus within science	Instruments	Reliability
Kelly (1978)	902, 1,010	+.16	+.10	Age 14, United States	Biology	Ach tests prepared for the International Assoc for the Evaluation of Educational Achievement: sci, sci activity, sci expectations, sci in the world	
		+.18	+.12		Chemistry		
		+.19	+.10		Physics		
		+.15	+.09		General science		
				Cognitive ability/affect			
Cohen (1979)	114, 109	+.29	−.43	Grade 8, math		Verbal problem-solving/interest in computation	.79 .79
		+.09	+.19			Verbal problem-solving/Kuder Interest	.79
Dunlop & Fazio (1977)	29, 34	−.21	+.17	Grade 8, science	Abstract ability/abstract preference	Test of Abstract Reasoning Abstract Preference Survey	 .68
Welch (1969)	125, 82	+.11	+.14	High school physics students	Physics	Science Process knowledge Course Satisfaction (physics)	.86 .80

Note. See appendix for full references of studies.

[a] Signs of correlations may vary from those reported in the original documents because it was necessary that they be placed on the same scale: Female = 1, Male = 2.

algebraically derived—and reflected data from nearly 28,000 students. The studies are tabulated in Table I, together with age and description of the sample, disciplinary focus within science, description and reliability of measurement instruments used, and the numerical value of the correlational indices.

Coding and Compilation

Each of the studies screened for synthesis was numerically coded using a specially prepared scheme developed to reflect information relating to the goals of this review. In addition to descriptions of the sample and psychometric properties of measuring instruments, variables chosen for coding included source of report, quality of study, and factors jeopardizing generalizability (Campbell & Stanley, 1966) such as reactive effects of experimental arrangements, and interaction effects between selection biases and the experimental variable. The corpus of studies was coded twice by the first author, in order to reliably reflect definitional refinements that were made as the coding procedure progressed (Cooper, Note 1). Differences were resolved by checking the original document. As a final step, intercoder reliability was calculated with data provided by a second rater who coded a randomly selected subset of 10 studies. Intercoder agreement was established at 92 percent.

Several negative findings related to characteristics of the synthesized studies deserve special mention before substantive findings are discussed. In the present synthesis, year-of-publication data indicated that correlations of the variables—affect, achievement, and cognitive ability—with gender did not vary significantly across 5-year time segments. This finding contrasts with that of a number of investigators who have reported that sex differences are decreasing in recent years as teachers, parents, and students are primed to an awareness of inequities in the educational system (Maccoby & Jacklin, 1974; Tohidi, Note 2). The nonsignificant effects of "quality of study" found in the present study are also of interest. 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 that design features do not significantly influence results (Williams, Haertel, Haertel, & Walberg, 1982). Smith, Glass, and 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). Size of sample, another variable potentially influencing outcome, was also found in this synthesis not to relate significantly to size of correlation ($\bar{r}_{xy} = -10$ for all independent samples).

In interpreting the findings of this synthesis, several points should be noted. First, the correlations appearing in the tables represent sample sizes ranging from 35 to 1,842 subjects. Second, when examining patterns across the three constructs, it should be kept in mind that although mean reliabilities were similar for measures of achievement, affect, and cognitive ability (.83, .80, and .84 respectively), the validity of affective outcomes may be weak because the instruments used in the studies may not have been sensitive enough to reveal differences among students who have neutral or mixed feelings about science. Third, most of the correlations, though significantly different from zero, are small. In some cases, this general finding is consistent with expectations based on earlier noncorrelational work (Hyde, 1981; Steinkamp & Maehr, in press; Tohidi, Note 2). Because of the effects that ability, affect, and achievement potentially exert on the social and academic lives of students, particularly females (Maehr, in press), it is important that both small and large differences be analyzed and described as fully as the data allow.

Results and Discussion

Gender Correlations

To what extent are science achievement, cognitive ability, and science affect related to gender? Do boys achieve better in science, excel in cognitive ability, and exhibit more positive affect toward science than do girls? Table II shows the relationships in Tukey stem and leaf diagrams (Tukey, 1976). The first decimal place of the correlation is represented on the stem to the left of the vertical line; the second place is represented as a "leaf" to the right of the vertical line. For example, the highest and lowest gender-with-achievement correlations are .65 and −.06. Mean correlations shown in Table II were computed using raw correlations from the individual studies. In addition, a "weighted mean" was calculated, with each correlation weighted by the reciprocal of the number of usable correlations reported for a given independent sample of subjects. "Sample" rather than "study" was used as the independent unit because some studies provided correlations on several independent units, such as age groups, classrooms, or schools. Thus, the procedure used here was to weight each independent sample equally, a procedure that satisfied the independence requirements of inferential procedures and also made it unnecessary to aggregate the findings above levels at which many interesting relationships could be studied. Several observations can be made from the data summarized in Table II.

Gender-with-achievement. The gender-with-achievement correlations indicate that males achieve slightly higher in science than do females ($p < .001$; $t = 4.0$; $df = 17$: Fisher's Z-transformation). This finding is in accord with a larger effort (Steinkamp & Maehr, Note 3) that reported that across 458 comparisons of male and female group means, a small but pervasive and statistically significant superiority was observed for males. This finding also supports conclusions reported by Gardner (1974) in a review of the literature, and by Comber and Keeves (1973), Keeves (1973), and Kelly (1978), who found slightly higher achievement scores for males in samples from 19 developed and undeveloped countries across the world.

The presence of patterns across subcategories of data suggest that different factors are operative across different content areas within science and different age levels. Part of the explanation for boys' relatively higher achievement in physics ($\bar{r}_{xy} = .25$, two independent correlations with 1,050 and 50 subjects) may be related to pupils' perceptions of the subject as masculine. Using a semantic differential scale, Weinreich (Note 4) found that students perceive physics, math, and engineering as masculine subjects, whereas biology is viewed as more feminine. The masculine image of physics is perpetuated in schools, where physics teachers and physics students are predominantly male (Walberg, 1967), and in textbooks (Weitzman & Rizzo, 1974). Also, physics appears more sensitive to out-of-school learning than

TABLE II

Correlations Between Gender and Achievement, Gender and Cognitive Ability, and Gender and Affect (Female = 1, Male = 2)

	Gender/Achievement		Gender/Cognitive ability		Gender/Affect	
	.7		.7		.7	38
	.6	5	.6		.6	
	.5		.5	6	.5	2
	.4		.4	7	.4	0184
	.3		.3	023445689	.3	00069
	.2	34567	.2	11122235556667789	.2	1112234689
	.1	113668	.1	01279	.1	112345556689
	+.0	069	+.0	00222223444445566667	+.0	00122244557889
	−.0	226	−.0	00035	−.0	14667889
	−.1		−.1	01128	−.1	223667899
	−.2		−.2	026	−.2	2566
	−.3		−.3	26	−.3	0457
	−.4		−.4		−.4	0
	−.5		−.5		−.5	2569
	−.6		−.6		−.6	0
Unweighted mean	.16*	(18)	.11*	(68)	.03	(79)
Standard deviation	.16		.19		.28	
Weighted mean	.17	(15 independent samples)	.13	(42 independent samples)	.06	(22 independent samples)
Biology	.13	(4)[a]	.10	(2)	−.11	(7)
Chemistry	.01	(3)	.04	(6)	−.25	(9)
Physics	.25	(2)	−.01	(3)	−.01	(10)
General Science	.19	(9)	.12	(57)	+.10	(53)
Postsecondary	−.04	(2)				
High school	.17	(7)	.05	(11)	−.03	(46)
Junior high	.28	(4)	.12	(16)	.14	(26)
Elementary	.12	(5)	.16	(30)	.05	(6)

[a] Numbers of correlations given in parentheses do not always sum to the total because some studies did not report on these categories.

*$p < .05$, H_0: $\rho_{xy} = 0$, H_A: $\rho_{xy} > 0$.

other branches of science, and boys' out-of-school learning is more relevant to physics achievement than is girls'. Presumably, boys are more likely to repair appliances, tinker with engines, and engage in investigative activities (Walberg, 1967), whereas girls are more likely to play "house" and care for plants and pets. A measure of out-of-school learning may be inferred from 10-year-old children's achievement in science, because few pupils have received extensive formal instruction by that age. In an international study, Kelly (1978) reports that sex differences at age 10 are minimal in biology and chemistry but pronounced in physics. She concludes that boys' greater achievement in physics may be a function of their learning more physics through out-of-school activities than girls do.

Boys' relatively higher achievement scores at the junior high age level ($\bar{r}_{xy} = .28$; four independent correlations with a total of 2,073 subjects) can possibly be explained in part by preadolescent boys' attempts to enhance their manliness by achieving in science, whereas many girls in that age group attempt to enhance their femininity by not achieving in science.

Gender-with-cognitive ability. This relationship is significant ($p < .001$; $t = 5.0$; $df = 67$: Fisher's Z-transformation) but slightly weaker than the gender-with-achievement relationship. This is not the first meta-analysis in which sex differences in cognitive ability were found to be small yet persistently in favor of males (Tohidi, Note 2). Hyde (1981) applied quantitative techniques to Maccoby and Jacklin's (1974) review of studies examining quantitative ability, visual-spatial ability, and field articulation. Males in the studies scored higher than females; medians of the standardized group differences scores ($\bar{X}_M$-$\bar{X}_F/S$) were found to be .43, .45, and .51 respectively. These gender differences were shown to account, however, for no more than 1 to 5 percent of the population variances.

In discussing the practical implications of small sex differences, Hyde illustrates how relatively small mean differences can generate rather large differences in the tails of the distributions. For example, given a standardized group mean difference of .40, 7.35 percent of males and 3.22 percent of females will fall above the 95th percentile cutoff sometimes applied in procedures for admittance to special programs of study. Whether or not differences of this magnitude are of practical significance is a moot point. Despite their small magnitude, the very pervasiveness of slightly higher scores for males has the potential to legitimate stereotypical attitudes and behaviors.

Boys' higher scores on cognitive measures may relate to the manner in which they spend free time. Some kinds of play and games provide a psychological environment in which important cognitive learning can take place (Mead, 1934; Piaget, 1965; Roberts & Sutton-Smith, 1962). Differences in the kinds of play activities that boys and girls engage in—in a reward system structured for males—suggest markedly different learning experiences for members of the two sexes. For example, Lever (1978) showed that boys' play is more complex in structure than is girls' play. Boys' play more frequently involves specialization of roles, interdependence of players, explicit group goals, larger group membership, numerous rules, and team divisions. Girls' play tends to be less motoric and manipulative than boys' (Lewis, 1972). Kleiber (Note 5) reports that leisure activities of boys are typically more complex, more exploratory, and more agentic. Furthermore, play activities of boys have been shown to be related to problem-solving ability (Vandenberg, 1978) and can serve as a partial explanation for boys' slightly higher scores on measures of cognitive ability.

Gender-with-affect. The influence of gender on affective variables is negligible in the synthesized studies ($\bar{r}_{xy} = .03$). When gender-with-affect data are categorized by age level, junior high boys' affect scores, like their achievement scores, are more positive than junior high girls' scores. Boys' more positive attitudes in science at this age may reflect attempts by both boys and girls to conform to traditional stereotypes of science as a masculine domain which is capable of capturing the interest of boys but not girls. The negative correlations for biology (−.11) and chemistry (−.25) indicate that girls' feelings about these subjects are more positive than boys' and counter the assertion that females do less well in the classroom and avoid careers in biology and chemistry because they are less interested in the subjects than boys are (Gardner, 1974; Keeves, 1973)

The findings reported in Table II serve to explain some of the confusion concerning sex differences in science achievement, cognitive ability, and science affect. When averaged across science discipline and across age brackets, the correlations of gender-with-achievement and gender-with-cognitive ability are significant but not large; when data are categorized by academic discipline and age bracket, however, more definite patterns become apparent. Moreover, none of the gender-with-achievement and gender-with-cognitive ability subcategories exhibit substantially negative correlations indicative of higher scores for females; the gender-with-affect subcategories, on the other hand, are largely negative. Despite the presence of these patterns, an important conclusion to be drawn from data in Table II is that the influence of gender on achievement, cognitive ability, and affect in science is small. Additional mediating variables must be sought if sex differences in adult achievement in science are to be more fully explained.

Correlations Between Variables

Turning now to correlations between pairs of variables, the question becomes: To what extent are science achievement, cognitive ability, and science affect interrelated, and does gender modify the relationship? The individual correlations are shown in Table III as "leaves" in the Tukey diagram.

Achievement-with-cognitive ability. Mean correlations between achievement and cognitive ability are significantly positive for boys ($\bar{r}_{xy} = .36$; $p < .001$; $t = 10.00$; $df = 29$: Fisher's Z-transformation) and for girls ($\bar{r}_{xy} = .32$; $p < .001$; $t = 7.95$; $df = 29$: Fisher's Z-transformation), suggesting, as expected, that higher levels of cognitive ability are indeed associated with higher levels of achievement in science.

Patterns for boys and girls in the integrated samples are strikingly similar, with the largest sex difference occurring at the high school level. The slightly weaker relationship for high school girls validates the often-observed tendency of girls with high levels of cognitive ability to underachieve in science during the years when it can be a social advantage for them to do so. For both boys and girls, the achievement-with-cognitive ability relationship is strongest in biology and physics.

Achievement-with-affect. Table III shows that the relationship between achievement and affect is small but greater than zero for males ($\bar{r}_{xy} = .19$; $p < .001$; $t = 5.94$; $df = 11$: Fisher-Z transformation) and for females ($\bar{r}_{xy} = .18$; $p < .001$; $t = 4.87$; $df = 11$: Fisher Z-transformation). Stronger correlations had been anticipated because both the affect and achievement measures were specific to science. These results, however, are similar to those of Willson (Note 6) who reported a correlation of .14 in a meta-analysis of studies in which affect and achievement were specific to science. The correlation between achievement and affect is slightly stronger, at least for girls, at the high school level than at the junior high level. This pattern supplements findings of Meyer and Penfold (1961), who report that the relationship between interest and achievement in school science increases during early high school years.

Table III shows that achievement-with-affect correlations are similar for boys and for girls, a finding which was not anticipated. Research in the area of mathematics indicates that mechanisms underlying the achievement-with-affect construct do differ across sexes (Aiken & Dreger, 1961). The occupational relevance of academic work is sometimes considered less for girls than for boys, so girls'

TABLE III

Correlations Between Achievement and Cognitive Ability, Achievement and Affect, and Cognitive Ability and Affect

	Achievement/Cognitive ability				Achievement/Affect				Cognitive ability/Affect			
	Boys		Girls		Boys		Girls		Boys		Girls	
	.7	14	.7	0	.7		.7		.7		.7	
	.6		.6	667	.6		.6		.6		.6	
	.5	1117	.5		.5		.5		.5		.5	
	.4	36777	.4	0112357	.4		.4		.4		.4	
	.3	14455666999	.3	01122468	.3	8	.3	355	.3		.3	
	.2	449	.2	0114	.2	288	.2	07	.2	9	.2	
	.1	23	.1	179	.1	56889	.1	002	.1	1	.1	479
	+.0	234	+.0	336	+.0	23	+.0	379	+.0	9	+.0	
	−.0		−.0		−.0		−.0		−.0		−.0	
	−.1		−.1	4	−.1		−.1		−.1		−.1	
	−.2		−.2		−.2		−.2		−.2	1	−.2	
	−.3		−.3		−.3		−.3		−.3		−.3	
	−.4		−.4		−.4		−.4		−.4		−.4	3
	−.5		−.5		−.5		−.5		−.5		−.5	
	−.6		−.6		−.6		−.6		−.6		−.6	
	−.7		−.7		−.7		−.7		−.7		−.7	
Unweighted mean	.36*	(30)	.32*	(30)	.19*	(11)	.18*	(11)	.07	(4)	.02	(4)
Standard deviation	.18		.20		.11		.11		.21		.30	
Weighted mean	.39		.39		.19		.23		.03		.01	
	(5 independent samples)				(5 independent samples)				(6 independent samples)			
Biology	.58	(4)[a]	.57	(4)	.17	(4)	.15	(4)				
Physics	.42	(7)	.46	(7)	.16	(3)	.26	(3)				
General science	.29	(19)	.22	(19)	.24	(3)	.17	(3)				
Chemistry					.18	(1)	.12	(1)				
High school	.29	(18)	.21	(18)	.20	(7)	.23	(7)				
Junior high	.54	(8)	.56	(8)	.17	(4)	.10	(4)				
Elementary	.32	(4)	.36	(4)								

[a] Numbers of correlations given in parentheses do not always sum to the total because some studies did not report on these categories.

$*p < .05$, H_o: $\rho_{xy} = 0$, H_A: $\rho_{xy} > 0$.

achievement might plausibly be more affected than boys' by factors such as liking for science. Conversely, girls are expected to be more compliant—willing to do what the school expects of them and work even at subjects they dislike—whereas boys are expected to be erratic and work only when a subject catches their interest. In this synthesis, the largest disparity between correlations for males and females occurs in the area of physics. A possible explanation for the weaker relationship between boys' affect and achievement in physics lies in the fact that existing stereotypes make it socially advantageous for boys but not girls to achieve in physics whether they like the subject or not.

Difficulties associated with the measurement of affective outcomes cannot be used as an explanation for failure to find stronger achievement-with-affect correlations, however, because the mean reliability associated with affect measures in this synthesis is .80 (reliabilities for individual instruments are shown in Table I). A more plausible reason is that the overall score used to represent a multiplicity of affective variables related to science may have resulted in a "canceling out" effect. A nonlinear relationship between affect and achievement could also explain why the correlational index was not larger.

Schock (1973) proposes an inverse relationship between liking and achieving in science within certain age groups. His data suggest that in the elementary years, children who are developing positive attitudes toward science may be achieving less rapidly. Schock explains this relationship by suggesting that teaching methods that focus on promoting a liking for science in elementary pupils may result in less rapid achievement, thus contributing to an inverse relationship between affect and achievement. At postsecondary levels, Schock's model suggests that higher rates of achievement are associated with diminished liking for science. This relationship is consistent with the notion that incessant demands for achievement at the postsecondary level have a negative effect on students' good feelings for the subject, again resulting in an inverse relationship. The notion of an inverse relationship between affect and scholastic achievement is supported in data reported by Cole, Jacobs, Zubok, Fagot, and Hunter (1962) and is supported in part by data provided by Tamir (1974). Inverse relationships are not supported in the present synthesis, because none of the mean correlations between achievement and affect were negative.

Cognitive ability-with-affect. Intuitively, it would seem that students with the ability to do science would like science, in which case data on cognitive ability and science affect would be strongly related. The synthesized studies showed, however, that the expected relationship does not exist for boys or for girls ($\bar{r}_{xy} = .07$ and .02, six independent samples, 268 boys and 225 girls).

Relationships Among Pairs of Correlations

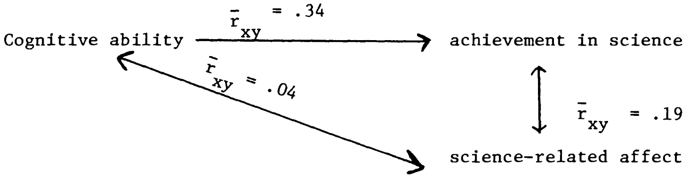
The problem of cause and effect frequently emerges in situations in which variables are examined contiguously (Bledsoe, 1967; Gill, Note 7). For example, studies by Lamy (1965) and Wattenburg and Clifford (1962) support the proposition that affect significantly influences achievement in school, whereas studies by Diller (1954), Gibby and Gibby (1967) and Centi (1965) support the alternate proposition that performance in school significantly influences certain aspects of affect. The complexity of the problem suggests that the relationships will not be fully described in the near future. For our purposes, it seems reasonable to suggest that affect and achievement reinforce each other; that is, a change in one facilitates a change in the other. A person with positive affect will meet problems expecting to achieve and will act in ways that bring about achievement. The effect of lower achievement on the development of negative attitudes is a frequent observation.

The synthesized studies provide information concerning the relative strengths of relationships among affect, achievement, and cognitive ability within the area of science. Figure 1 shows that cognitive ability is a better predictor of science achievement than is science-related affect. This result supports one body of research (Keeves, 1972; Marjoribanks, 1976; Sewell & Hauser, 1975; Shea, 1976). For example, Marjoribanks studied regression-fitted relationships within a variety of disciplines and showed that cognitive scores have stronger associations with achievement than do measures of school-related affect. Another body of research provides evidence that affect is more strongly related to achievement than is cognitive ability. Bridgham (1969) found that the relationship between cognitive ability and achievement varied across academic disciplines. He showed that cognitive scores of boys correlate negatively with reading achievement, but positively with achievement on an electrostatics test. Taken together, these patterns of findings suggest that the comparatively strong relationship between cognitive ability and achievement may be unique to science, at least in the early grades within the public school setting.

These issues and the relationships shown in Figure 1 suggest that *in pedagogical situations in which achievement in science is the immediate goal, good cognitive ability is more important than is positive affect.*

To extrapolate, to achieve in science requires more than good intentions (cf. Maehr, in press). It requires ability. This may be similarly true for all school subjects, but it does appear to be especially true for school science. Thus, the development of cognitive capacities provides, at least in the short run, a surer route to achievement in school science than does the cultivation of positive affect. Moreover, Figure 1 suggests that positive affect is enhanced as ability is actualized in achievement. In some respects, this is a troubling finding. Does this mean that we ought to forget about affective outcomes in science? Not really. What it seems to suggest is that the liking of science is an outcome that is derived in large measure from having actualized one's potential in this regard—and done well. Thus, one is

FIGURE 1. Graphic representation of data in Table III, using averages of boys' and girls' unweighted means.



not advised to forget about affective outcomes. But, most especially, one is not advised to forget about achievement. It appears that as students acquire and demonstrate knowledge and proficiency they are most likely to develop a positive attitude toward science.

Conclusion

It all seems simple enough: One should like what one does well and do well what one likes. Simple it may be; correct it is not. If nothing else, this review and synthesis of the literature revealed a much more complex pattern of relationships among ability, achievement, and attitude, at least in the area of school science. But we suggest it has done more than that. It may have clarified a point or two about what the literature does or does not say. It may have raised a question about policy and practice. We believe, most especially, that is provides a degree of focus for future research.

In accord with other reviews, it was found that boys do better in school science than girls do. The differences are slight, but they appear to be reliable. Similarly, in tests of cognitive ability associated with science, boys tend to score higher. The differences are not overwhelming, but they are there. But girls do not appear to like science less. Indeed, in two notable cases (Biology and Chemistry) they like science a great deal more. The pattern does not conform to the simple observation that we like that which we do well and do well that which we like.

A closer look at the results, however, prompts a particularly interesting line of questioning. Comparison of the various ability, achievement, and attitude correlations suggested that one is perhaps most likely to feel positively toward science as one actualizes one's ability through science achievement. Moreover, one can interpret the results as suggesting that it is primarily the acquisition of proficiency that leads to positive attitudes. Moving yet one more step beyond the specifics of our results, we suggest a question of special interest for future research into the origins of gender differences in science achievement. Cultural stereotypes, expectations, and inhibitions stemming from the notion that "science is not for girls," have either been overcome or simply do not intrude into the elementary or secondary classroom context. However, culture and society may be playing a more subtle role in differentially shaping aptitude and achievement through early, and largely *extra*-school, experiences. In any event, one might suggest that attempts to enhance the performance of young girls in science must go beyond mere "consciousness raising." The focus must also be on cognitive socialization. Whereas this occurs as often outside as inside school walls, the school will inevitably be asked to do something. What it can do in this regard seems to be the top agenda item for future research (cf., Grieb & Easley, in press).

What has been said thus far is based on a quantitative synthesis of available research. Obviously, one might make a number of points about what was *not* in the literature. We will limit ourselves to one such point. Studies of science attitude abound, but studies based on a thorough motivational analysis of science achievement are virtually nonexistent (cf. Maehr, in press). Thus, regardless of whether they like or dislike science, girls may hold quite different achievement goals. Although we may conclude that there must be more to science instruction than "attitude building," there is no evidence that motivation is unimportant in explaining gender differences in science achievement. Indeed, it is our judgment that the study of cognitive socialization could be profitably complemented by incorporating the concerns and insights of cognitive theories of motivational development (cf. Nicholls, in press).

Reference Notes

1. Cooper, H. M. *Scientific guidelines for conducting integrative literature reviews.* Paper presented at the annual meeting of the American Educational Research Association, New York, March 1982.
2. Tohidi, N. *Sex differences in cognitive functioning: A meta-analysis of studies on Piagetian tasks.* Dissertation in preparation, University of Illinois, 1982.
3. Steinkamp, M. W., & Maehr, M. L. *Sex-related differences in science achievement: A quantitative synthesis of research.* Paper in preparation.
4. Weinreich, H. *What sex is science?* Paper presented at the Sex-role Stereotyping Conference, University of Cardiff, Wales, 1977.
5. Kleiber, D. *The leisure experience of males and females: A context for androgynous behavior.* Paper presented at the research symposium of the National Recreation and Park Association, New Orleans, October 1979.
6. Willson, V. L. *A meta-analysis of the relationship between student attitude and achievement in secondary school science.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston, April 1980.
7. Gill, M. P. *Pattern of achievement as related to the perceived self.* Paper presented at the annual meeting of the American Educational Research Association, Los Angeles, 1969.

References

Aiken, L. R., & Dreger, R. M. The effect of attitudes on performance in mathematics. *Journal of Educational Psychology,* 1961, *52,* 19–24.

Bledsoe, J. Self-concept of children and their intelligence, achievement, interests, and anxiety. *Childhood Education,* 1967, *43,* 436–438.

Bloom, B. S. *Taxonomy of educational objectives: Cognitive domain.* New York: David McKay Company, 1956.

Bridgham, R. Classification, seriation, and learning of electrostatics. *Journal of Research in Science Teaching,* 1969, *6,* 118–127.

Brodie, T. A. Attitude toward school and academic achievement. *Personnel and Guidance Journal,* 1964, *43,* 375–378.

Campbell, D. T., & Stanley, J. C. *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally College Publishing, 1966.

Centi, P. Self-perception of students and motivation. *Catholic Education Review,* 1965, *63,* 307–319.

Cole, D., Jacobs, S., Zubok, B., Fagot, B., & Hunter, I. The relation of achievement imagery scores to academic performance. *Journal of Abnormal and Social Psychology,* 1962, *65,* 208–211.

Comber, L. C., & Keeves, J. P. *Science education in nineteen countries: An empirical study.* New York: John Wiley & Sons, 1973.

Cooper, H. M., & Rosenthal, R. Statistical versus traditional procedures for summarizing research findings. *Psychological Bulletin,* 1980, *87*(3), 442–449.

Diedrich, R. *Teacher perceptions as related to teacher-student similarity and student satisfaction with school.* Unpublished doctoral dissertation, University of Chicago, 1966.

Diller, L. Conscious and unconscious self-attitudes after success and failure. *Journal of Personality,* 1954, *23,* 1–12.

Doran, R. L., & Sellers, B. Relationships between students' self-concept in science and their science achievement, mental ability, and gender. *Journal of Research in Science Teaching,* 1978, *15*(6), 527–533.

Eysenck, H. J. An exercise in mega-silliness. *American Psychologist,* 1978, *33,* 517.

Finger, J. A., & Schlesser, G. E. Academic performance of public and private school students. *Journal of Educational Psychology,* 1968, *54,* 118–122.

Gardner, P. L. Sex differences in achievement, attitudes, and personality of science students: A review. *Research in Science Education,* 1974, *4,* 231–258.

Gibby, R. G., Sr., & Gibby, R. G., Jr. The effects of stress resulting from academic failure. *Journal of Clinical Psychology,* 1967, *23,* 35–37.

Glass, G. V. Integrating findings: The meta-analysis of research. In L. S. Shulman (Ed.), *Review of research in education* (Vol. 5). Itasca: Peacock, 1978.

Goldfried, M. R., & D'Zurilla, T. J. Prediction of academic competence by means of the survey of study habits and attitudes. *Journal of Educational Psychology,* 1973, *64,* 116–122.

Grieb, A., & Easley, J. A primary school impediment to mathematical equity: Case studies in rule-dependent socialization. In M. Steinkamp & M. Maehr (Eds.), *Women in science (Recent advances in motivation and achievement)* (Vol. 2). Greenwich, Conn.: JAI Press, in press.

Husen, T., Fagerlind, I., & Liljefors, R. Sex differences in science achievement and attitudes: A Swedish analysis by grade level. *Comparative Education Review,* 1974, *18,* 292–304.

Hyde, J. How large are cognitive gender differences? *American Psychologist,* 1981, *36*(8), 892–901.

Inhelder, B., & Piaget, J. *The growth of logical thinking from childhood to adolescence.* New York: Basic Books, 1958.

Jackson, P. W., & Lahaderne, H. M. Scholastic success and attitude toward school in a population of sixth graders. *Journal of Educational Psychology,* 1967, *58*(1), 15–18.

Kahn, S. B. Affective correlates of academic achievements. *Journal of Educational Psychology,* 1969, *60,* 216–221.

Keeves, J. P. *Educational environment and student achievement.* Stockholm: Almqvist & Wiksell International, 1972.

Keeves, J. P. Differences between the sexes in mathematics and science courses. *International Review of Education,* 1973, *19,* 47–63.

Kelly, A. *Girls and science: An international study of sex differences in school achievement.* Stockholm: Almqvist & Wiksell International, 1978.

Lamy, M. W. Relationship of self-perceptions of early primary children to achievement in reading. In I. J. Gordon (Ed.), *Human development. Readings in research.* Chicago: Scott, Foresman and Company, 1965.

Landman, J. T., & Dawes, R. M. Psychotherapy outcome: Smith and Glass' conclusions stand up under scrutiny. *American Psychologist,* 1982, *37,* 504–516.

Lever, J. Sex differences in the complexity of children's play and games. *American Sociological Review,* 1978, *43,* 471–483.

Lewis, M. Culture and gender roles: There is no unisex in the nursery. *Psychology Today,* 1972, *5,* 54–57.

Light, R. J., & Smith, P. V. Accumulating evidence: Procedures for resolving contradictions among different research studies. *Harvard Educational Review,* 1971, *41*(4), 429–471.

Maccoby, E., & Jacklin, C. *The psychology of sex differences.* Stanford, Calif.: Stanford University Press, 1974.

Maehr, M. L. On doing well in science: Why Johnny no longer excels: Why Sarah never did. In S. Paris, G. Olson, & H. Stephenson (Eds.), *Learning and motivation in the classroom.* Hillsdale, N.J.: Lawrence Erlbaum & Sons, in press.

Malpass. L. F. Some relationships between students' perceptions of school and their achievement. *Journal of Educational Psychology,* 1953, *44,* 475–482.

Marjoribanks, K. School attitudes, cognitive ability, and academic achievement. *Journal of Educational Psychology,* 1976, *68*(6), 653–660.

McBee, G., & Duke, R. L. Relationships between intelligence, scholastic motivation, and academic achievement. *Psychological Reports,* 1960, *3,* 3–8.

Mead, G. H. *Mind, self, and society.* Chicago: University of Chicago Press, 1934.

Meyer, G. R., & Penfold, D. M. E. Factors associated with interest in science. *British Journal of Educational Psychology,* 1961, *31,* 33–37.

Nicholls, J. (Ed.). *The development of achievement motivation (Recent advances in achievement motivation)* (Vol. 3). Greenwich, Conn: JAI Press, in press.

Piaget, J. *The moral judgment of the child.* New York: Free Press, 1965.

Presby, S. Overly broad categories obscure important differences between therapies. *American Psychologist,* 1978, *33,* 514–515.

Rachman, S. *The effects of psychotherapy.* London: Pergamon Press, 1971.

Roberts, J. M., & Sutton-Smith, B. Child training and game involvement. *Ethnology,* 1962, *1,* 166–185.

Schock, N. H. An analysis of the relationship which exists between cognitive and affective educational objectives. *Journal of Research in Science Teaching,* 1973, *10,* 299–315.

Sewell, W. H., & Hauser, R. M. *Education, occupation, and earnings.* New York: Academic Press, 1975.

Shea, B. M. Schooling and its antecedents: Substantive and methodological issues in the status attainment process. *Review of Educational Research,* 1976, *46,* 463–526.

Smith, M. L., Glass, G. V, & Miller, T. I. *The benefits of psychotherapy.* Baltimore, Md.: Johns Hopkins University Press, 1980.

Steinkamp, M. W. Motivational style as a mediator of adult achievement in science. In M. Steinkamp & M. Maehr (Eds.), *Women in science (Recent advances in motivation and achievement)* (Vol. 2). Greenwich, Conn.: JAI Press, in press.

Steinkamp, M. W., & Maehr, M. L. Gender differences in motivational orientations toward achievement in school science: A quantitative synthesis. *American Educational Research Journal,* in press.

Tamir, P. A comparative study of students' achievement in botany and zoology. *Journal of Biological Education,* 1974, *8,* 333–342.

Tukey, J. W. *Exploratory data analysis.* Reading, Mass.: Addison-Wesley, 1976.

Vandenberg, B. Play and development from an ethological perspective. *American Psychologist,* 1978, *33,* 724–738.

Walberg, H. J. Dimensions of scientific interests in boys and girls studying physics. *Science Education,* 1967, *51*(2), 111–116.

Wattenburg, W. W., & Clifford, C. *Relationship of self-concept to beginning achievement in reading.* United States Office of Education, Cooperative Research Project No. 377. Detroit: Wayne State University, 1962.

Weitzman, L., & Rizzo, D. Images of males and females in elementary school textbooks in five subject areas. In *Biased textbooks.* Washington, D.C.: National Foundation for the Improvement of Education, 1974.

Williams, P. A., Haertel, E. H., Haertel, G. D., & Walberg, H. J. The impact of leisure-time television on school learning: A research synthesis. *American Educational Research Journal,* 1982, *19,* 19–50.

Williams, R. L. Personality, ability, and achievement correlates of scholastic attitudes. *Journal of Educational Research,* 1970, *63,* 401–403.

APPENDIX

List of Synthesized Studies

Allen, L. R. An evaluation of children's performance on certain cognitive, affective, and motivational aspects of the interaction unit of the science curriculum improvement study elementary science program. *Journal of Research in Science Teaching,* 1972, *9,* 167–173.

Allen, L. R. An evaluation of children's performance on certain cognitive, affective, and motivational aspects of the systems and subsystems unit of the science curriculum improvement study elementary science program. *Journal of Research in Science Teaching,* 1973, *10,* 125–134.

Ashbaugh, A. C. Selection of geological concepts for intermediate grades. *Science Education,* 1968, *52,* 189–196.

Babikian, Y. An empirical investigation to determine the relative effectiveness of discovery, laboratory, and expository methods of teaching science concepts. *Journal of Research in Science Teaching,* 1971, *8,* 201–209.

Bowyer, J. B., & Linn, M. C. Effectiveness of the science curriculum improvement study in teaching scientific literacy. *Journal of Research in Science Teaching,* 1978, *15,* 209–219.

Bredderman, T. Elementary school science experience and the ability to combine and control variables. *Science Education,* 1974, *58,* 457–469.

Bridgham, R. G. Classification, seriation, and the learning of electrostatics. *Journal of Research in Science Teaching,* 1969, *6,* 118–127.

Carnes, P. E., Bledsoe, J. C., & VanDeventer, W. C. Programmed materials in seventh-grade open-ended laboratory experiences. *Journal of Research in Science Teaching,* 1967, *5,* 385–396.

Cline, V. B., Richards, J. M., & Needham, W. E. Creativity tests and achievement in high school science. *Journal of Applied Psychology,* 1963, *47,* 184–189.

Cohen, M. P. Scientific interest and verbal problem solving: Are they related? *School Science and Mathematics,* 1979, *79,* 404–408.

Dale, L. G. The growth of systematic thinking: Replication and analysis of Piaget's first chemical experiment. *Australian Journal of Psychology,* 1970, *22,* 277.

DeLuca, F. P. Measurement of logical thinking: An electronic equivalent of Piaget's first chemical experiment. *Journal of Research in Science Teaching,* 1977, *14,* 53–54.

DeLuca, F. P. Application and analysis of an electronic equivalent of Piaget's first chemical experiment. *Journal of Research in Science Teaching,* 1979, *1,* 1–11.

Doran, R. L. Misconceptions of selected science concepts held by elementary school students. *Journal of Research in Science Teaching,* 1972, *9,* 127–137.

Doran, R. L., & Sellers, B. Relationships between students' self-concept in science and their science achievement, mental ability, and gender. *Journal of Research in Science Teaching,* 1978, *15,* 527–533.

Douglas, J. D., & Wong, A. C. Formal operations: Age and sex differences in Chinese and American children. *Child Development,* 1977, *48,* 689–692.

Dunlop, D. L., & Fazio, F. Piagetian theory and abstract preferences of secondary science students. *School Science and Mathematics,* 1977, *77,* 21–26.

Field, T. W., & Cropley, A. J. Cognitive style and science achievement. *Journal of Research in Science Teaching,* 1969, *6,* 2–10.

Fraser, B. J. Some attitude scales for ninth grade science. *School Science and Mathematics,* 1978, *78,* 379–384.

Goldschmid, M. L. Different types of conservation and nonconservation and their relation to age, sex, IQ, MA, and vocabulary. *Child Development,* 1967, *38,* 1229–1246.

Haladyna, T., & Thomas, G. *The attitudes of elementary school children toward school and subject matters.* Paper presented at the annual meeting of the American Educational Research Association, New York, April 1977. (ERIC Microfiche Ed 139837)

Hart, E. P. Examination of BSCS Biology and Nonbiology students' ecology comprehension, environmental information level, and environmental attitude. *Journal of Research in Science Teaching,* 1978, *15,* 73–78.

Hofman, H. An assessment of eight-year-old children's attitudes toward science. *School Science and Mathematics,* 1977, *7,* 662–670.

Hofstein, A., Ben-Zvi, R., Samuel, D., & Tamir, P. Attitudes of Israeli students toward chemistry and physics: A comparative study. *Science Education,* 1977, *61,* 259–268.

Jahoda, G. On the nature of difficulties in spatial-perceptual tasks: Ethnic and sex differences. *British Journal of Psychology,* 1979, *70,* 351–363.

Jahoda, G. Sex and ethnic differences on a spatial-perceptual task: Some hypotheses tested. *British Journal of Psychology,* 1980, *71,* 425–431.

Keeves, J. P. The home, the school, and achievement in mathematics and science. *Science Education,* 1975, *59,* 439–460.

Kelly, A. *Girls and science: An international study of sex differences in school science achievement.* Stockholm: Almqvist & Wiksell International, 1978.

Keogh, B. K. Pattern copying under three conditions of an expanded spatial field. *Developmental Psychology,* 1971, *4,* 25–31.

Lawson, A. E. Sex differences in concrete and formal reasoning ability as measured by manipulative tasks and written tasks. *Science Education,* 1975, *59,* 397–405.

Lazarowitz, R., & Lazarowitz, R. H. Choices and preferences of science subjects by junior high school students in Israel. *Journal of Research in Science Teaching,* 1979, *16,* 317–323.

Liben, L. S. Performance on Piagetian spatial tasks as a function of sex, field dependence, and training. *Merrill-Palmer Quarterly,* 1978, *24,* 97–110.

Linn, M. C., & Levine, D. I. Adolescent reasoning: Influence of question format and type of variables on ability to control variables. *Science Education,* 1978, *62,* 377–388.

Lowell, W. E. The development of hierarchical classification skills in science. *Journal of Research in Science Teaching,* 1980, *17,* 425–433.

Lowery, L. F., Bowyer, J., & Padilla, M. J. The science curriculum improvement study and student attitudes. *Journal of Research in Science Teaching,* 1980, *17,* 327–355.

Lynch, P. P., Benjamin, P., Chapman, T., Holmes, R., McCammon, R., Smith, A., & Symmons, R. Scientific language and the high school pupil. *Journal of Research in Science Teaching,* 1979, *16,* 351–357.

Marek, E. A. Correlations among cognitive development, intelligence quotient, and achievement of high school biology students. *Journal of Research in Science Teaching,* 1981, *18,* 9–14.

Marjoribanks, K. School attitudes, cognitive ability, and academic achievement. *Journal of Educational Psychology,* 1976, *68,* 653–660.

Marjoribanks, K. The relation between students' convergent and divergent abilities, their academic performance, and school-related affective characteristics. *Journal of Research in Science Teaching,* 1978, *15,* 197–207.

Maxwell, J. W., Croake, J. W., & Biddle, A. P. Sex differences in the comprehension of spatial orientation. *The Journal of Psychology,* 1975, *91,* 127–131.

Meyer, G. R. Reactions of pupils to Nuffield science teaching project trial materials in England at the ordinary level of the general certificate of education. *Journal of Research in Science Teaching,* 1970, *7,* 283–302.

Nelson, G. K. Concomitant effects of visual, motor and verbal experiences in young children's concept development. *Journal of Educational Psychology,* 1976, *4,* 466–473.

Peterson, K., Kauchak, D., & Yaakobi, D. Science student's role-specific self-concept: Course, success, and gender. *Science Education,* 1980, *64,* 169–174.

Pettus, A. M., & Haley, C. D., Jr. Identifying factors related to science process skill performance levels. *School Science and Mathematics,* 1980, *80,* 273–276.

Piburn, M. D. *Sex, field dependence and formal thought.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Cincinnati, Ohio, March 1977.

Power, C. Changes in students' attitudes towards science in the transition between Australian elementary and secondary schools. *Journal of Research in Science Teaching,* 1981, *18,* 33–39.

Raven, D. J., & Adrian, S. M. Relationships among science achievement, self-concept, and Piaget's operative comprehension. *Science Education,* 1978, *62,* 471–479.

Robertson, W. W., & Richardson, E. The development of some physical science concepts in secondary school students. *Journal of Research in Science Teaching,* 1975, *12,* 319–329.

Rowell, J. A. Sex differences in achievement in science and the expectations of teachers. *The Australian Journal of Education,* 1971, *5,* 16–29.

Ryman, D. Teaching methods, intelligence, and gender factors in pupil achievement on a classification task. *Journal of Research in Science Teaching,* 1977, *5,* 401–409.

Saarni, C. I. Piagetian operations and field independence as factors in children's problem-solving performance. *Child Development,* 1973, *44,* 338–345.

Schock, N. H. An analysis of the relationship which exists between cognitive and affective educational objectives. *Journal of Research in Science Teaching,* 1973, *10,* 229–315.

Sieveking, N. A., & Savitsky, J. S. Evaluation of an achievement test prediction of grades, and composition of discussion groups in college chemistry. *Journal of Research in Science Teaching,* 1969, *6,* 374–376.

Skinner, R., Jr. Inquiry sessions: An assist for teaching science via instructional television in the elementary schools. *Journal of Research in Science Teaching,* 1968, *5,* 346–350.

Smith, W. S., & Schroeder, C. K. Instruction of fourth grade girls and boys on spatial visualization. In J. D. Novack (Ed.), *Science Education.* New York: John Wiley & Sons, 1979.

Tamir, P., & Amir, R. Teaching science to first and second grade pupils in Israel by the audio-tutorial method. *Science Education,* 1975, *59,* 39–49.

Tamir, P., Arzi, A., & Zloto, D. Attitudes of Israeli high school students towards physics. *Science Education,* 1974, *58,* 75–86.

Tamir, P., & Kempa, R. F. Cognitive preference styles across three science disciplines. *Science Education,* 1978, *62,* 143–152.

Thomas, B., & Snider, B. The effects of instructional method upon the acquisition of inquiry skills. *Journal of Research in Science Teaching,* 1969, *6,* 377–386.

Treagust, D. F. Gender-related differences of adolescents in spatial representational thought. *Journal of Research in Science Teaching,* 1980, *2,* 91–97.

Walberg, H. J. Dimensions of scientific interests in boys and girls studying physics. *Science Education,* 1967, *51*(2), 111–116.

Walberg, H. J. Physics, femininity, and creativity. *Developmental Psychology,* 1969, *1,* 47–54.

Wallach, M. A., & Kogan, N. *Modes of thinking in young children.* New York: Holt, Rinehart and Winston, 1966.

Welch, W. W. Correlates of courses satisfaction in high school physics. *Journal of Research in Science Teaching,* 1969, *6,* 54–58.

Za'Rour, G. I., & Panaouri-Kilaniotis, A. L. Analytic styles of categorization and conservation abilities among Greek Cypriot children. *Science Education,* 1977, *61*(1), 47–56.

Za'Rour, G. I. Conservation of weight across different materials by Lebanese school children in Beirut. *Science Education,* 1971, *55,* 387–394.

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