Programs for Mathematically Gifted Students: A Review of Empirical Research

Evelyn J. Sowell
Arizona State University West

Abstract

This paper summarizes and critiques the empirical research of the 1970s and 1980s on programs for mathematically gifted students. Much research has shown that accelerating the mathematics curriculum provides a very good program for precocious students. Organizational plans that place mathematically gifted students together for mathematics instruction also offer opportunities for these students to perform well. Although technology-based instruction also appears to provide an efficacious way of providing instruction for mathematically gifted elementary students, this method should be examined further with older students and in long-term studies. Research with enriched curricula and non-computer-based instruction provided inconclusive evidence of efficacy for mathematically gifted students.

In an earlier review. Sowell, Bergwall. Zeigler, and Cartwright (1990) examined the literature that describes and identifies mathematically gifted students. Based on the information available. they pointed out that no single definition of mathematical giftedness exists. The literature suggested that mathematically gifted students could be thought of as those who are precocious or those who engage in qualitatively different mathematical thinking.

This paper continues the review of empirical research, largely from the 70s and 80s. on instructional and organizational programs for mathematically gifted, talented, precocious, accelerated. or high-ability students. Included are all of the known reports of planned studies that provided information about both the purpose of a program and the results of its use with mathematically gifted students.

This review is especially pertinent given the curriculum reforms initiated by the National Council of Teachers of Mathematics (NCTM). In 1989 the NCTM published *Curriculum and Evaluation Standards for School Mathematics,* which calls for better mathematical performance by all K-12 students than in the past, especially in problem solving, communications, reasoning, and mathematical connections. *Standards* assumes a *common* curriculum for students in grades K-8 but recommends a differentiated program for high school students. As envisioned in *Standards*. students in grades 9-12 would study a core mathematics program that would be enriched for college-bound and capable students. Exceptionally talented students would continue into college-level work. *Standards* warns that "we [the NCTM] strongly recommend against acceleration t either omits content identified in these standards or advan students through it superficially" (NCTM, 1989, p. 124).

Purposes and Variables

Careful study of the reports located for this review sho three major purposes for research on programs for ma ematically gifted students. The studies were conducted in or to evaluate (a) the effects of accelerating and or enrich mathematics curricula, (b) methods of instruction, and (c) or nizational plans. In addition to the purpose of the study, t author gathered additional information about the grade lev of the students involved, the duration of the program, whetl the program was school-based, descriptions of the activities treatment and comparison groups, and results.

Because the author's interest is in programs that can be us profitably with mathematically gifted students during the sch year, it is important to know the degree to which the resea studies examined programs that were tried in schools. Stud were designated as school based if the mathematics taught students as part of the research project was their compl mathematics curriculum for the school year. For this revie programs requiring additional mathematics (e. g., beyond t regular mathematics curriculum) or programs offered in su mer were considered non-school-based programs.

About half the reports described treatment activities fo single group of participants. The remainder had one or mo comparison groups, designated either as an alternative tre ment or as a control group. Alternative treatment groups we those with students who were drawn from the same populati as the treatment group *and* the participants received an alter tive specialized treatment, for example, linear teaching strate or spiral teaching strategy. Control groups were study part

Putting the Research to Use

This review shows clearly that mathematically precocious students profit by participating in accelerated mathematics programs. Also, mathematically gifted students perform better when they work alongside other mathematically able students. Therefore, teachers and parents are encouraged to identify and develop programs or organizational plans that provide these opportunities for students. Elementary school teachers should make technology-based programs in mathematics available to their students, especially those who are mathematically able, because these programs appear to work well.

pants who did not receive specialized treatments and were used simply for comparison. If control groups represented the same population as their respective treatment group(s), the controls were designated as an equivalent group (E). Controls with students from populations other than those of their treatment group(s) were designated as nonequivalent groups (N). As is true in other research, studies having equivalent comparison groups are usually subject to fewer validity threats than those with nonequivalent groups (Campbell & Stanley, 1966).

Results of studies about both cognitive and affective variables were also gathered. Studies having only one treatment group typically reported pre and posttreatment results, whereas those with comparison groups provided comparative information from the groups.

Organization of Review

This review is organized according to the major purposes of research on programs for mathematically gifted students. Sections include studies involving acceleration and enrichment programs, studies involving instructional methods, and studies involving organizational plans. Within each major section are the findings from research followed by a discussion. The final major section provides conclusions and recommendations based on these reviews.

Studies Involving Acceleration and Enrichment Programs

This section presents results from 22 studies in which acceleration and/or enrichment of the curriculum for mathematically gifted students was the primary focus. Fourteen studies evaluated accelerating the curriculum; 5 studies, enriching the curriculum; and 3 studies, combining acceleration and enrichment.

Acceleration programs

The studies that featured accelerating the curriculum for mathematically gifted students showed consistently that mathematically gifted students can learn mathematics very well and much more quickly than the regular mathematics curriculum allows (Bartkovich & Mezynski, 1981 (two studies); Bodine, Ross, & Gill, 1982; Brody & Fox, 1980; Collins, 1986; Croll, 1985; Fox, 1974, 1976; George & Denham, 1976; House, 1981; Mezynski, Stanley, & McCoart, 1983; Stanley, 1976 (two studies), 1985; Stanley & McGill, 1986). Most of these projects grew out of the Study for Mathematically Precocious Youth (SMPY) program, originated by Julian C. Stanley at Johns Hopkins University in the early 70s. Stanley and his associates showed that fast paced programs featuring diagnostic testing followed by prescriptive teaching enabled both males and females to move through the mathematics curriculum quickly. Follow through studies showed that 24 of 25 educationally accelerated students who began college earlier than usual also received degrees early. Of this group, 4 received master's degrees simultaneously with their baccalaureate (Stanley, 1985; Stanley & McGill, 1986).

Of the 14 acceleration studies, 12 involved seventh- and eighth-grade students, and 2 studies involved students in grades 8-12 (Stanley, 1976 [study 2]; Stanley, 1985; Stanley & McGill, 1986). Four acceleration studies were school based, 8 were *not* school based, and 2 were mixed. The mixed studies ran partly in summer and partly during the school year (Bodine et al., 1982; George & Denham, 1976). None of these acceleration studies used a comparison group because the researchers wanted to assist all of the mathematically gifted students they could locate without the restrictions that experimental design requires (Stanley & Benbow, 1986).

Using tutorials, summer classes, and other nonconventional approaches, Stanley and his colleagues produced dramatic changes in achievement when mathematically gifted students were offered opportunities to learn at a faster-than-usual pace. For example, Croll (1985) showed that students, mostly seventh graders, learned in 40 hours the mathematics content that usually takes 270 hours. Only one finding contradicted this set of very positive results. Brody (1985) found that accelerated mathematics coursework in a summer program had little or no effect on scores from the Scholastic Aptitude Test for Mathematics of seventh graders.

Enrichment programs

Table 1 provides information about five studies involving enrichment programs for mathematically gifted students. The studies are arranged in alphabetical order of the authors' names with additional information about the grade levels, duration of the treatment, designation as school based (*Y* for yes, *N* for no), descriptions of the activities of the treatment and control groups, and the results.

As shown in Table 1, treatments varied in the five studies and so did results. Treatment groups in the Koukeyan (1977) (fourth graders only) and Weaver (1987) studies performed better on cognitive measures than their respective control groups. By comparison, treatment groups in Gratz and Pulley (1984), Koukeyan (1977) (grades 5 6), and Morningstar (1983) did not perform differently as a result of treatment. On affective measures the treatment groups in Gratz and Pulley (1984), Koukeyan (1977) (fourth graders only), and Wagner and Zimmerman (1986) showed positive results, but treatment groups of fifth and sixth graders in Koukeyan's study and Morningstar's (1983) high school students did not show results different from those of the control groups.

Acceleration and enrichment programs

Three studies, none of which used a comparison group, tested a combination of accelerating and enriching the curriculum for mathematically gifted students. Moore and Wood (1988) found that third- through seventh-grade students who reasoned well according to their test scores could learn mathematics more quickly than they would have in the regular graded school curriculum. In addition to acceleration, the program also contained a variety and depth of topics not usually available to elementary school students. Four of 17 students completed the arithmetic curriculum by the end of the first year of the program. By the end of the second year, all students had made progress in mathematics achievement, study habits, time management skills, self esteem, and self-confidence.

In a year long program. Muller (1985) also found that seventh graders homogeneously grouped in an acceleration enrichment program made significant increases in achievement and had positive attitudes toward mathematics. Lunny's (1983) 3 year study of mathematically talented eighth graders showed these students able to move through the high school mathematics sequence more quickly than the usual program allowed. In addition to their regular mathematics coursework during the school year, students took a weekly 2-hour class in the evening. During their fourth year of high school they were able to take calculus at the local community college.

Discussion of acceleration and/or enrichment studies

The three acceleration-enrichment studies bear a close resemblance to the SMPY studies because each used a fast-paced program along with additional mathematics. Because the design and the outcomes were similar to SMPY outcomes, these studies are discussed as part of the acceleration group.

Stanley and Benbow (1986) provided a rationale for acceleration of mathematically gifted students that is quite compelling. In all their studies *mathematically gifted* is synonymous with *precocious*. Students in their research were known to reason well because each had to score high on the Scholastic Aptitude Test in Mathematics in order to participate in the programs. Therefore, when the researchers stated that the pacing of educational programs must be responsive to the capacities and knowledge of individual students, they had in mind students with the particular capability of reasoning well in mathematics. Stanley and his associates considered and discarded the idea of educational enrichment and chose instead to adapt existing curricula to the needs of younger students.

Accounts of these studies are too brief to determine the extent to which the curricula conform to each NCTM standard. However, all the acceleration and acceleration-enrichment studies with upper elementary through eighth grade ($N = 13$) showed that gifted students could learn mathematics more quickly than the regular curriculum allowed whether they were school- or non-school-based programs. Given these successes, it is highly doubtful that the mathematical capabilities of stu-

Table 1
Studies Involving Enrichment of Mathematics Curricula

Study	Grade Level(s)	Duration	School-Based	Treatment	Control	Results
Gratz & Pulley 1984	9-12	School year, 45 minutes daily	Y	Program for students whose parents were migrant workers; focus on problem-solving skills in mathematics, English, and social studies	None	Students scored achievement gains, but not significantly; student evaluations showed improvement in feelings of self-worth, ability to assume responsibility for learning, appreciation of academic achievement, and development of social skills.
Koukeyan 1977	4-6	6.5 months, 60-70 minutes daily	Y	Vertical-horizontal enrichment program; objectives on level plus some at next higher level, plus enrichment activities	Regular program, objectives at grade level	Significant gains in achievement and attitude for fourth graders in enrichment program compared to regular program; for Grades 5-6 gains were not significantly different for groups
Morningstar 1983	9-12	Two classroom periods +45 minutes over 4-week period	N	Self-instructional enrichment modules	Regular school program	No significant differences were noted between groups on algebra achievement or attitude.
Wagner & Zimmerman 1986	7	School year, 3 hours per week	N	Emphasis on informal mathematics, problem finding, and problem creating; having fun with mathematics; learning about social behavior and responsibility	None	Formal evaluation not used with volunteer students; students persisted in attending Saturday sessions and in investing much of their free time in challenging mathematics.
Weaver 1987	Preschool	5 weeks, 3 hrs/wk	Y	Enriched instruction in mathematics and language	No treatment group—students from waiting list	Enriched instruction groups made higher scores than the no treatment group on intelligence and vocabulary.

dents such as these would be served well by curricula conforming to the NCTM *Standards* where the differentiated curriculum is intended only for high school students.

Whereas the meaning of *acceleration* as used by researchers is clear, the meaning of *enrichment* as used here is ambiguous. Koukeyan's reference to a vertical-horizontal program with objectives both on and above grade level, though it lacks specificity, approaches an operational definition. However, the remaining four studies do not explain clearly what is meant by enrichment. This term appears to mean anything extra that is part of the curriculum, for example, more freedom than in regular classrooms to explore concepts and pursue individual interests (Gratz & Pulley, 1984) and informal mathematics as an open process of thought (Wagner & Zimmerman, 1986). Because the treatments appear to share no common characteristics, attempting to generalize about the results is meaningless.

Studies Involving Instructional Methods

In this section 11 studies are reviewed that sought information about the effects of instructional methods for mathematically gifted students. Seven studies, with primarily elementary school students, made extensive use of microcomputers and are reviewed as a group. The remaining 4 studies with high school students used a variety of teaching methods.

Computer-assisted instructional (CAI) programs

In five studies researchers found that computers assisted mathematically gifted students in learning problem-solving skills (Hersberger, 1983; Hersberger & Talsma, 1985; Hersberger & Wheatley, 1989 (two studies); Robinson & Stanley, 1989). In both long-term studies lasting a school year or more, treatment groups outperformed equivalent control groups of students (Hersberger, 1983; Robinson & Stanley, 1989).

Although results from the previous studies indicated advantages for CAI, results from other studies of CAI with gifted students were equivocal. Kanevsky (1985) compared two groups using CAI in combination with cooperative-competitive goal structures with a traditional group using flashcard drills. All three groups improved in mathematics achievement, but there were no significant differences among the groups. Steele, Battista, and Krockover (1982) compared students using computer-assisted drill and practice with those using individualized drill and practice without computers and found no significant differences. Table 2 (p. 130) presents summary information about each CAI study.

Non-computer-assisted instructional programs

Short-term studies of mathematically gifted high school students showed that special instructional treatments produced positive results in most cases. When an inductive teaching strategy was compared to a deductive teaching strategy for building models, both groups improved following instruction and the deductive strategy produced better results (Bailey, 1982).

Two investigators studied the effects of altering instructional methods for teaching problem solving. Fowler (1978) found that a linear teaching strategy produced better results than a spiral teaching strategy, and Hall (1976) found that both situational heuristics and planning heuristics training allowed students to perform better than an equivalent control group on situational and well-defined problems. However, Cunningham (1984) found that self-instructional training did not produce significant differences between a treatment group and a nonequivalent control group in reflectivity or mathematics achievement. Summary information about these studies is shown in Table 3 (p. 131).

Discussion of studies of instructional methods

Hersberger's (1983) and Robinson and Stanley's (1989) findings strongly suggest that mathematically gifted students using technology based instructional methods perform well on problem-solving tasks. These results contradict those of Steele et al. (1982) and Kanevsky (1985) and probably reflect the content taught rather than the instructional method employed. Whereas the first set of researchers sought to have students learn content that is conceptually challenging (problem solving), the second group of researchers taught routine content (drill and practice).

The research on instructional methods without computers, although yielding some positive results, was short-term. Each of the four high school studies was dissertation research, of which three projects were not school-based. The brevity of instruction is unusual, particularly since three studies (Bailey, 1982; Fowler, 1978; Hall, 1976) considered problem solving as the content focus. These studies were of such short duration that generalization of their results is not plausible.

Studies Involving Organizational Plans

The seven studies that evaluated different organizational plans for mathematically gifted students are described in Table 4 (p. 132). Regardless of the organizational plan used, students in treatment groups outperformed students in either equivalent or nonequivalent control groups on achievement tests (Griffin, 1984; Hepp, 1979; Parke, 1983).

In three of the four studies without control groups, students in the treatment groups did better on tests than comparable groups of mathematically gifted students receiving a second treatment (DeComo, 1979; Peters, 1980; Still, 1981). Only the Flores (1980) study produced results that differed from this pattern. His study found that mathematically gifted students in a special purpose school did not differ significantly in achievement from those in a regular school. However, students in the regular school had more positive attitudes toward school than those in the special purpose school.

Discussion of studies of organizational plans

All the studies in this section were relatively long-term with six of the seven operating a school year or longer. That six of the seven studies were also school based makes the findings even more convincing. Typically, gifted students in one treatment group experienced fewer opportunities for interacting with other gifted students than did the other treatment group, for example, a part time gifted program versus a full-time program, heterogeneously grouped students versus homogeneously grouped students, and so forth. This suggests that the preferred organizational plan may be one in which mathematically gifted students have ample opportunities to associate with their peers. Gifted students typically find mutually rewarding exchanges with other gifted students (Brounstein, Holahan, & Sawyer, 1988; Janos, 1986).

Conclusions and Recommendations

This review was conducted to examine information about programs for mathematically gifted students who are precocious as well as those who engage in qualitatively different thinking. The Johns Hopkins SMPY researchers have shown that accelerating the mathematics curriculum is a good plan for precocious students who reason well, whether in school- or non-school-based programs. For students who may be gifted because they do qualitatively different mathematical thinking, there is no evidence concerning the efficacy of acceleration, and indeed such evidence might be suspect if it existed.

A common theme apparent in the accounts of the SMPY projects is the notion that precocious students enjoy working alongside others who are precocious; the fast pace appears to be invigorating. Therefore, it seems possible that the successes of certain organizational plans may be due to the degree to which mathematically gifted students are allowed to work and socialize together. Situations in which students spend greater amounts of time together appear to be conducive to greater achievement and more positive attitudes than situations in which time with peers is limited.

Given the paucity of studies and the lack of a clear definition of enrichment in those that were reviewed, it is impossible to draw conclusions about the efficiency of enrichment programs for mathematically gifted students. Again, however, it is important to keep in mind which meaning of *gifted* is used. Long term school-based studies should be designed that describe clearly what is meant by enrichment both for mathematically precocious students and for students who do qualitatively different mathematical thinking. Only then can enrichment be evaluated satisfactorily.

This review has produced evidence that technology-based instruction is valuable for mathematically gifted students in elementary school for problem solving. What is needed is an extension of this line of research to junior and senior high school. The push for problem solving in the NCTM *Standards* (1989) and increased availability of technology should make this a priority among researchers in gifted education.

Regardless of the reader's preferred definition of *mathematical giftedness*, the evidence is substantial that alternative mathematical programs should be provided for these students. To subject bright students to the regular program as their only opportunity in mathematics is to shortchange them and our society. We must find ways to increase their possibilities for learning mathematics.

Author's Note

My appreciation goes to Linda Bergwall, Rose Cartwright, and Alice Zeigler for their assistance in collecting research reports. Also, I thank Philip Swicegood, Ronald Zambo, and Ray Buss for their helpful comments on earlier versions of this paper.

References

Bailey, R. E. (1982). A study comparing two methods of teaching mathematical model building to gifted secondary mathematics students. *Dissertation Abstracts International, 43,* 710A. (University Microfilms No. 82 19500)

Bartkovich, K. G., & Mezynski, K. (1981). Fast paced precalculus mathematics for talented junior high students: Two recent SMPY programs. *Gifted Child Quarterly, 25,* 73-80.

Bodine, R., Ross, A., & Gill, T. (1982). Mathematics education for gifted secondary students: An evaluative study. St. Louis, MO: MEGSSS National Model Project, CEMREL, Inc. (ERIC Document Reproduction Service No. ED 225 810)

Brody, L. E. (1985). The effects of an intensive summer program on the SAT scores of gifted seventh graders. *Dissertation Abstracts International, 46,* 132A-133A. (University Microfilms No. 85-06966)

Brody, L., & Fox, L. H. (1980). An accelerative intervention program for mathematically gifted girls. In L. H. Fox, L. Brody, & D. Tobin (Eds.), *Women and the mathematical mystique* (pp. 164-178). Baltimore, MD: Johns Hopkins University Press.

Brounstein, P. J., Holahan, W., & Sawyer, R. (1988). The expectations and motivation of gifted students in a residential academic program: A study of individual differences. *Journal for the Education of the Gifted, 11,* 36-52.

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

Collins, E. L. (1986). Ability, academic achievement, and aspiration of mathematically gifted males and females. *Dissertation Abstracts International, 46,* 2219A-2220A. (University Microfilms No. 85 23062)

Croll, R. L. (1985). The assessment of a community college based on fast-paced mathematics program for the gifted. *Dissertation Abstracts International, 46,* 918A-919A. (University Microfilms No. 85-12545)

Cunningham, J. A. (1984). A comparison of math achievement between mathematically able and regular math students following self-instruction training. *Dissertation Abstracts International, 45,* 1688A. (University Microfilms No. 84-14144)

DeComo, M. J. (1979). A study of the academic achievement of gifted students in a special program. *Dissertation Abstracts International, 39,* 7280A. (University Microfilms No. 79 12510)

Flores, H. E. (1980). A study of the academic achievement and attitudes of gifted and talented elementary school students. *Dissertation Abstracts International, 40,* 5265A. (University Microfilms No. 80-05584)

Fowler, E. C. (1978). A study interrelating situational problem solving, mathematical model building, and divergent thinking among gifted secondary mathematics students. *Dissertation Abstracts International, 39,* 2111A-2112A. (University Microfilms No. 78-17574)

Fox, L. H. (1974). A mathematics program for fostering precocious achievement. In J. C. Stanley, D. P. Keating, & L. H. Fox (Eds.), *Mathematical talent: Discovery, description, and development* (pp. 101 125). Baltimore, MD: Johns Hopkins University Press.

Fox, L. H. (1976). Sex differences in mathematical precocity: Bridging the gap. In D. P. Keating (Ed.), *Intellectual talent: Research and development* (pp. 183 214). Baltimore, MD: Johns Hopkins University Press.

George, W. C., & Denham, S. A. (1976). Curriculum experimentation for the mathematically talented. In D. P. Keating (Ed.), *Intellectual talent: Research and development* (pp. 103 131). Baltimore, MD: Johns Hopkins University Press.

Gratz, E., & Pulley, J. L. (1984). A gifted and talented program for migrant students. *Roeper Review, 6,* 147-149.

Griffin, C. B. (1984). An analysis of learning styles, achievement, and higher cognitive processes in three programs for gifted urban elementary school students (Doctoral dissertation, Temple University, 1984). *Dissertation Abstracts International, 45,* 1637A.

Hall, T. R. (1976). A study of situational problem solving by gifted high school mathematics students (Doctoral dissertation, Georgia State University, 1976). *Dissertation Abstracts International, 36*, 906A-907A.

Hepp, D. A. (1979). The effects of a gifted mathematics program on the attitudes and achievement of secondary school students identified as academically gifted. *Dissertation Abstracts International, 40*, 1326A. (University Microfilms No. 79 17425)

Hersberger, J. R. (1983). The effects of a problem-solving oriented mathematics program on gifted fifth grade students. *Dissertation Abstracts International, 44*, 1715A. (University Microfilms No. 83-23998)

Hersberger, J. R., & Talsma, G. (1985). Summer courses in computing for the gifted and talented: How much can be accomplished in two weeks? *Roeper Review, 8*, 39-41.

Hersberger, J. R., & Wheatley, G. (1989). Computers and gifted students: An effective mathematics program. *Gifted Child Quarterly, 33*, 106-109.

House, P. A. (1981). One small step for the mathematically gifted. *School Science and Mathematics, 81*, 195-199.

Janos, P. M. (1986). The socialization of highly intelligent boys: Case material from Terman's correspondence. *Journal of Counseling and Development, 65*, 193-195.

Kanevsky, L. (1985). Computer-based mathematics for gifted students: Comparison of cooperative and competitive strategies. *Journal for the Education of the Gifted, 8*, 239-255.

Koukeyan, B. B. (1977). Evaluation of a vertical-horizontal enrichment program for the math gifted students fourth, fifth, and sixth grades (Doctoral dissertation, Brigham Young University, 1976). *Dissertation Abstracts International, 37*, 5587A.

Lunny, J. F. (1983). Fast-paced mathematics classes for a rural county. In C. P. Benbow & J. C. Stanley (Eds.), *Academic precocity: Aspects of its development* (pp. 79-85). Baltimore, MD: Johns Hopkins University Press.

Mezynski, K., Stanley, J. C., & McCoart, R. F. (1983). Helping youths score well on AP examinations in physics, chemistry, and calculus. In C. P. Benbow & J. C. Stanley (Eds.), *Academic precocity: Aspects of its development* (pp. 86-112). Baltimore, MD: Johns Hopkins University Press.

Moore, N. D., & Wood, S. S. (1988). Mathematics in elementary school: Mathematics with a gifted difference. *Roeper Review, 10*, 231-234.

Morningstar, K. G. (1983). Self-teaching enrichment modules on modern applications of mathematics for talented secondary students and evaluation of effective utilization through an original prediction model. *Dissertation Abstracts International, 44*, 1715A. (University Microfilms No. 83 24117)

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

Muller, E. W. (1985). Evaluation of a science/mathematics gifted education program for junior high school students. *Dissertation Abstracts International, 46*, 655A. (University Microfilms No. 85 10158)

Parke, B. N. (1983). Use of self-instructional methods of gifted primary aged students. *Gifted Child Quarterly, 27*, 29-34.

Peters, D. S. (1980). The elementary principal's role in developing and implementing an individualized education program for gifted students: A case study. *Dissertation Abstracts International, 40*, 6097A. (University Microfilms No. 80-11172)

Robinson, A., & Stanley, T. D. (1989). Teaching to talent: Evaluating an enriched and accelerated mathematics program. *Journal for the Education of the Gifted, 12*, 253-267.

Sowell, E. J., Bergwall, L., Zeigler, A. J., & Cartwright, R. M. (1990). Identification and description of mathematically gifted students: A review of empirical research. *Gifted Child Quarterly, 34*, 147-154.

Stanley, J. C. (1976). Special fast-mathematics classes taught by college professors to fourth through twelfth graders. In D. P. Keating (Ed.), *Intellectual talent: Research and development* (pp. 132-159). Baltimore, MD: Johns Hopkins University Press.

Stanley, J. C. (1985). Young entrants to college: How did they fare? *College and University, 60*, 219-228.

Stanley, J. C., & Benbow, C. P. (1986). Youths who reason exceptionally well mathematically. In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of giftedness* (pp. 361-387). New York: Cambridge University Press.

Stanley, J. C., & McGill, A. M. (1986). More about "young entrants to college: how did they fare?" *Gifted Child Quarterly, 30*, 70-73.

Steele, K. J., Battista, M. T., & Krockover, G. H. (1982). The effect of micro computer-assisted instruction upon the computer literacy of high ability students. *Gifted Child Quarterly, 26*, 162-164.

Still, J. H. (1981). Gifted student achievement in full-time and part-time programs. *Dissertation Abstracts International, 42*, 2077A. (University Microfilms No. 81 24458)

Wagner, H., & Zimmermann, B. (1986). Identification and fostering of mathematically gifted students. *Educational Studies in Mathematics, 17*, 243-259.

Weaver, J. H. (1987). The effectiveness of an enrichment program for academically talented preschool children. *Dissertation Abstracts International, 47*, 2879A. (University Microfilms No. 86 26163)

Table 2
Studies Involving Computer-Assisted Instruction (CAI)

Study	Grade Level(s)	Duration	School-Based	Treatment 1	Treatment 2	Control	Results
Hersberger 1983	5	School year	Y	Calculators and microcomputers used extensively by experimental group in problem solving	None	Regular school program—E	Experimental group performed better than control group on advanced math topics and computation measures; no significant differences were noted between groups on rates of learning, enjoyment of mathematics, value of mathematics, and self-concept.
Hersberger & Talsma 1985	6-10	2 weeks, summer	N	Computer programming as an aid to mathematical problem solving	None	None	Students improved scores on test of BASIC programming.
Hersberger & Wheatley 1989 (study 1)	5	Unknown	Y	Calculators and microcomputers used extensively by experimental group in problem solving	None	None	Students used heuristics successfully in problem solving, learned persistence, and were motivated to write computer programs in BASIC.
Hersberger & Wheatley 1989 (study 2)	6	3 weeks	N	Computer programming in Pascal as an aid to problem solving	None	None	Students received grades of A and B; became better and more independent problem solvers following treatment.
Kanevsky 1985	3-4	10 days, .25 hours each day	Y	Cooperative learning group using CAI	Competitive learning group using CAI	Traditional—E Flashcard drills	No significant differences were found in math achievement by groups; all groups improved in math achievement from pretest to posttest; no significant differences in either socialization or competition indices; students in competitive groups felt winning was more important than it had been prior to treatment.
Robinson & Stanley 1989	2-7	4 hours weekly, 3 school years	Y	Instruction on math concepts and nonroutine problems; problem solving and LOGO on microcom puters	None	Nonparticipants in program—E	Program participants scored higher on traditional achievement battery; Grades 3, 4, 5 program participants outperformed nonparticipants in problem solving; participants had positive attitudes toward math activities and reported smaller gaps between opportunities and preferences for activities than the nonparticipants.
Steele, Battista, & Krockover 1982	5	9 months	Y	Computer assisted drill and practice program used	None	Individualized drill and practice without computers—E	No significant differences were noted in mathematics achievement; computer-assisted groups outperformed the non-computer-assisted group on affective, cognitive, and composite computer literacy measures.

Table 3
Studies Involving Instruction Without Computers

Study	Grade Level(s)	Duration	School-Based	Treatment 1	Treatment 2	Control	Results
Bailey 1982	9-12	4 weeks	N	Applications-to-Model (ATM) teaching strategy	Model-to-Applications (MAT) teaching strategy	None	On ability to construct mathematics models, both groups scored higher on posttests than pretests, with MAT significantly higher. No significant change was noted in attitude toward mathematics or independence of judgment.
Cunningham 1984	9-12	5 weeks, 5 sessions of 15 minutes each	Y	Self-instructional training	None	Regular school program—N	No significant differences were noted either in reflectivity or mathematics achievement.
Fowler 1978	9-12	3 weeks, 15 sessions of 1.25 hours each	N	Linear teaching strategy	Spiral teaching strategy	Control—E	Both treatment groups scored higher than the control group in applying heuristics of situational problem solving; linear group outperformed spiral group; spiral group increased in independence of judgment but linear group unchanged; neither teaching strategy produced changes in attitudes toward mathematics.
Hall 1976	9-12	25 minutes	N	Situational heuristics strategy	Planning heuristics strategy	Control—E	Situational heuristics group outperformed other two groups, and planning heuristics group outperformed control group on situational problems; planning group outperformed control group on well-defined problems.