Research Related to the Algebra Project's Intervention to Improve Student Learning in Mathematics

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The Algebra Project is a multi-component intervention that sites use to improve student learning in mathematics. The components include: instructional materials for the classroom and for afterschool programs; teacher training and support for implementation; community development and youth leadership development.

Middle School Implementations

The goal of the Algebra Project's work in middle schools was to prepare students with the mathematics background and motivation that would enable them to pass an Algebra I course in grade 8 or 9. During the 1990s, a number of middle schools implemented the project in urban or rural sites. In the classroom, teachers used the project's pre-algebra materials called the *Transition Curriculum,* and supplemented them as needed to meet their local curriculum objectives. Algebra Project trainers facilitated summer workshops and provided teacher support during the school year.

In 1994-95, a national expert panel evaluated the implementations in six schools that were implementing the project in the Mississippi Delta and Jackson (NSF grant ESI9450258). The panel concluded:

> The Algebra Project is an important project with a potential to bring about systemic reform through implementing a middle school mathematics curricular invention, a teacher development process, and a community development process. Although in place for only two years, we observed positive outcomes in teaching, in students' attitudes and engagement around mathematical ideas, in community involvement, and in movement toward systemic reform. We believe strongly that the Project deserves funding to continue and to develop further in the areas outlined in the recommendations.[1] (Cazden et al., 1995)

[1] PANELISTS/CONSULTANTS: Courtney B. Cazden (Harvard University), Shirley H. Conner (Simmons High School, Hollandale, MS), Robert B. Davis (Rutgers University), Lisa D. Delpit (Georgia State University), Edgar L. Edwards (ret., Virginia State Dept. of Education), Jacqueline J. Irvine (Emory

This panel recommended that the materials be developed further, that teacher professional development be expanded, and that the project link with university-based mathematicians and math educators.

In 1996, the NSF funded teacher enhancement and community development in schools in Cambridge, MA; Brooklyn, NY; Jackson, MS; and several areas of the Mississippi Delta (ESI-9630116). Additional sites were developed in New Orleans, Charleston and St. Helena Island; SC; Bessemer, AL; and Weldon, NC, through the southern initiative of the Algebra Project, led by David Dennis. The nature and characteristics of professional development and community development were described, and students were tracked into high school from middle schools where more than half of the students had participated in the project's classroom instruction: the King Open Program in Cambridge, MA; the M.L. King Academic Middle School in San Francisco; and the Brinkley Middle School in Jackson, MS (see Table 1). (Project founder Bob Moses himself taught only one of the cohorts listed below, the Brinkley students who graduated in 1995-96; the other cohorts were taught by teachers trained in the project's instructional materials and pedagogy. The nature of community development and youth leadership development varied across sites and cohorts.)

Results

The schools selected for evaluation were those where at least half of the students had participated in the Algebra Project by grade 8 and where more than two cohorts had graduated from middle school. Those sites vary demographically. In Cambridge, African American students were a small minority in Cambridge, and only 10% of students qualified for free or reduced cost lunch. All students at Brinkley Middle School were African American, and free or reduced cost lunch was available to about 85% of students. At King Academic Middle School in San Francisco, 60-70% of the roughly 500 students qualified for free/reduced cost lunch during the years studied. About one third were African American; one-third Asians from many countries, 20% Latino, and others students were from the Philippines and Pacific Islands. The percentage of students who were English language learners ranged from 10-17%.

The indicator for project success was the percentage of students who were enrolling in college preparatory mathematics courses in high school. The course enrollment data was collected for the middle of the academic year when students had settled into their courses. The selection of students for comparison groups changed over time as we improved our methods of constructing these groups. Data for Jackson, MS, was provided by Dr. Willie Johnson, head of the district's Dept. of Planning and Evaluation. The first cohorts were compared to students from all other middle schools, whereas the later cohorts were compared with only three other middle schools most similar to Brinkley in racial

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University), Charles Payne (Northwestern University), and Kenneth J. Travers (University of Illinois/Champaign). STAFF: Frank E. Davis, Mary Maxwell West, Linda Harris, Wayne A. Williams, Lesley University.

composition and lunch status (from 60-90%). Students from these middle schools were tracked into all nine Jackson high schools. Data for San Francisco was provided by the districts research department with assistance of the director Ritu Khanna and assistant Donna Trousdale. The first cohorts were compared to all other students, whereas the later comparison was constructed only from students who had remained in their middle schools throughout grades 6-8, and to a group that was demographically (matching the proportions in the Algebra Project group on racial composition, gender, free lunch status, and incoming mathematics proficiency assessed by a national norm-referenced standardized test).

Table 1 shows that, across these diverse sites, Algebra Project students entered Geometry courses in Grade 9 at about twice the rate of students from other middle schools. Similarly, the proportion of Algebra Project students taking lower-level courses was lower than nonAlgebra Project students. This pattern continued into Grade 10, as shown in Table 2 (West, Davis, Lynch & Atlas, 1998; Davis & West, 2000; Currell & West, 2003; West & Davis, 2004).

A study of the characteristics of successful Algebra Project schools and teachers is being conducted by F. Davis, M. West and J. Greeno through an NSF/ROLE grant (0087664). They have drafted a chapter on how mathematics is discussed in the classrooms, and how the project's master teachers develop students' motivation to learn (Davis, West & Greeno, in press).

High School Implementations

Project founder Bob Moses began working at the high school level in 1996 (at Lanier High School in Jackson), in order to provide Algebra Project students graduating from Brinkley Middle School a continuation into high school of the project's instructional approach. Moses started by teaching Geometry to these students, but he soon saw the importance of addressing the needs of the many Grade 9 students who were struggling with Algebra I. Lanier has historically been the lowest performing of Jackson's nine high schools. The roughly 900 students are all African-American, and about 85% qualify for free or reduced-cost lunch. The enrollment in Grade 12 is usually only about half that in Grade 9, reflecting a high drop out rate.

Under Moses' program, the percentage of students taking college preparatory courses increased dramatically (see Table 3). Enrollment in Algebra I in Grade 9 increased from 12% in 1996 to 67% in 2002 (compared to an average of 45% across all other Jackson high schools). Grade 9 enrollment in courses ABOVE Algebra I grew from 1% to 22% (compared to 18% for other Jackson high schools). In Grade 10, enrollment in Geometry grew from 16% to 58% (compared to 39%) and from 16% to 24% for courses above Geometry (compared to 23%).[2]

[2] We thank Dr. Willie Johnson, Director of the Jackson Public Schools Dept. of Evaluation and Planning, for providing the data sets for these analyses.

In December 2002, the project received a grant from the NSF Instructional Materials Development program (ESI0137855) to design materials for high school Algebra I. A development team was formed that eventually included three university-based mathematicians (Greg Budzban of Southern Illinois; Ed Dubinski of Kent State, and David Henderson of Cornell). The Lanier High School is serving as the development site. Two grade 9 teachers in the Proviso district near Chicago pre-piloted some of the new materials in 2003-04; and four additional Grade 9 teachers in Irvington, NJ and Rochester, NY, piloted Algebra I materials in 2004-05. A full year of Algebra I materials has now been completed, which will be revised this summer based on last year's piloting. These materials can be easily extended or adopted to suit the specific standards for Algebra I in different states. A teachers' guide will also be produced. Grade 10 Geometry materials are now in development with support from a grant from the GE Foundation, to be piloted in Rochester district during 2005-06.

In formulating the new materials, the developers have paid careful attention to mathematical concepts that are present in the current quite strong national consensus about high school mathematics reform. These concepts are present in typical state standards for Algebra I and in some cases go beyond what students typically see (for example, matrix representation). Thus the Algebra I course aims to introduce students to some advanced topics as well as to give them a firm grounding in the concepts of slope and function that predominate in a typical Algebra I course. They also aim for students to be able to use formulas and equations with conceptual understanding, and to be adept with graphing calculators.

Performance on an Algebra I Test

Although none of the Grade 9 pilot sites gives a standardized test at the end of the year, students in the development site do have one. We examined students' performance on the Mississippi State Algebra Test as an indication of the potential of the materials to improve students' performance on a standardized test of beginning algebra.

The state of Mississippi has required all Algebra I students to take a final test since 1996. Passing the test recently became a requirement for high school graduation. The test was revised once in 2000-01, but has always consisted of about 70 multiple-choice items and several open-ended performance items. The multiple choice items are allocated among several assessment strands that are aligned with the state Algebra I standards. The 2003 version consisted of the following scorable items:[3]

Patterns, Relations, and Functions (5 items): Recognize, create, extend, and apply patterns, relations, and functions and their applications.

Equations and Inequalities (18 items): Recognize, classify and use real numbers and their properties; simplify algebraic expressions; solve and graph equations, inequalities and systems in one and two variables; communicate using the language of algebra.

Polynomials (9 items): Explore and communicate the characteristics and operations of polynomials.

[3] Mississippi Subject Area Testing Program Teachers' Guide, Algebra I (2001).

Formulas in Problem Solving (10 items): Utilize various formulas in problem-solving situations; communicate using the language of algebra.
Slope (8 items): Interpret and apply slope as a rate of change.
Probability (3 items): Analyze data and apply concepts of probability.
Open-Ended: (4 open-ended items concerning Equations and Inequalities).

The state reports a total score for each student that is scaled from 200-400, with the passing score set at 300. In addition, it provides raw scores of the number of items correct on each assessment strand, and for the open-ended items. Students are allowed to use graphing calculators on the exam. The achievement of Algebra Project students in Year 1 of the grant suggest that the materials have strong potential to improve performance in algebra (see Tables 4 and 5).

Gains from 2002 to 2003

Table 4 shows that the Algebra Project students' passing rate improved from 33% to 55% when using the new materials, and they performed significantly better than nonAlgebra Project students in the same school.[4] In 2001-02, nearly the entire 9th grade was using Algebra Project materials for at least part of the year. The nonAlgebra Project students were mainly students repeating 9th grade, who used a computer software tutoring program. In 2002-03, there is a larger comparison group of nonAlgebra Project students, who used an Algebra I textbook. There were three trained Algebra Project teachers (Moses, Bardige, and Quinn) who used Algebra Project materials, and two who did not use them. One of those two had been to some training but decided not to use the materials.

Comparison with Classes Using Algebra I Textbook

The mean scale score of Algebra Project students significantly exceeded that of nonAlgebra Project students ($p < .0005$), although the range was similar. The experienced Algebra Project "apprentice," Peggy Quinn, received the highest passing rate in the school: 71% of her 49 students passed. Her students also performed well on several sub-strands of the test. The high result achieved by this experienced teacher who was completely new to the Algebra Project shows that the Algebra Project materials can be successfully adopted by a new teacher, and can produce students who can pass a typical beginning algebra test on their first attempt.

This cohort of students has just completed Grade 11 and will attend a special summer program in Mississippi to prepare them for the ACT and advanced mathematics courses. (All of them have passed the Algebra I test.) We are collecting data on their nonAlgebra Project peers in order to compare the drop out rate, courses taken, grades, and number of attempts needed to pass the Algebra I test over the past two years.

In 2003-04, the Algebra Project at Lanier took on a special 9th grade cohort of over-age

[4] Placement into Algebra project or nonAlgebra Project classes was not dependent on student choice; students were placed by counselors according to convenience of scheduling.

students who had been attending a special middle school. From our classroom observations, it appears that some of these students are doing very well with the project's approach. These students took the state Algebra I test at the end of 10th grade in April 2005, and results are not yet available. Nationally, as the practice of "social promotion" has been eliminated, over-age students are accumulating who need new approaches to instruction. Therefore we will carefully examine the project's impact on these students.

Theory and Research Supporting the Project's Instructional Approach

The Algebra Project is unusual in its comprehensive and multifaceted approach to educational improvement, including community and youth development in addition to the usual components of classroom materials and teacher development. The project is also unusual in that its implementation strategies have been developed by members of the main target population (Treisman, 1997), and derive from lessons learned by project founder Bob Moses and colleague David Dennis during the work for voter registration during the 1960s.

Project founders and teachers hold an explicit learning theory called the "five step curricular process" that is used in all of the project's learning environments: the classroom, afterschool activities for students, youth-led workshops, teacher professional development workshops, and community/school meetings. Moses attributes these ideas to two sources: (1) to the ideas about the relationship between experience and learning that go back to Dewey, Piaget and Lewin, later synthesized into a pedagogical approach that is sometimes called "experiential learning"(Kolb, 1983); (2) the assertions of philosopher W.V.O.Quine (Moses' advisor at Harvard Graduate School) that elementary arithmetic, logic and set theory are based in "regimentation" of ordinary discourse. These two sources are reflected in the project's "Five Step Curricular Process." Events that are experienced by the whole group or class, such as a trip, are discussed in ordinary language and represented in pictures and essays. Next, students' language is structured into observational statements that can be confirmed as "true," which are later translated into the structures and symbolic representations used in conventional mathematics. These ideas (see Moses et al, 1989; and Moses & Cobb, 2001 for fuller discussion) provide the framework for all of the project's instructional materials.

There is a long history of research and debate on the theories of Piaget, or "experiential learning" that is related more or less directly to the project's approach. The project argues that, although experiential learning has been touted, curriculum designers have not shown exactly HOW to create learning from experiences. The current curriculum authors believe that the materials present a way to move step by step from certain experiences to conventional mathematical concepts and representations. Demonstrating this will require clinical research on how concepts develop in the minds of Algebra Project students. There is very strong current interest in the research community about such cognitive processes in mathematics learning (see, for example, van Oers, 2000; Cobb, Yackel & McClain, 2000).

There is some existing research, however, that does support aspects of the project's work.

In Algebra Project classrooms and after school activities, students often take on leading in which they display mathematical competence (Davis, et al, in press). The importance of these public demonstrations is consistent with Theresa Perry's finding that schools that produce high-achieving African American students engage in *public* demonstrations that communicate and celebrate high achievement (Perry, 2003).

Some research on "culturally responsive teaching" suggests that student learning is enhanced when learning involves familiar situations or when activities are based largely in students' own language (Cobb & Hodge, in press; Cobb, Stephan, McClain & Gravemeijer, 2001; Gutstein, Lipman, Hernandez & de los Reyes, 1997; Lipka & Adams, 2004; Moschkovich, in press; Schwartz & Martin, 2004). The Algebra Project, however, does not argue for "cultural relevance" but uses social processes that create social support for competence and a sense of group responsibility among students, whoever they may be. We observed that this approach was successful in classrooms that were culturally and linguistically diverse (San Francisco), as well as those that were more homogeneous (Jackson) (West and Currell, 2003; Davis, West and Greeno, in press).

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