Innovative Approach to Mathematics on Academically Low Achieving Students

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Abstract- This article presents results from a year-long study of an innovative approach to mathematics and its impact on students with learning disabilities as well as those at-risk for special education. There is a considerable interest in the field regarding current mathematics reform, particularly as it reflects the simultaneous and conflicting movements toward national standards and inclusion. Results suggest that innovative methods in mathematics are viable for students with average and above average academic abilities and that students with learning disabilities or those at-risk for special education need much greater assistance if they are to be included in general education classrooms. The success of the majority of students in this study raises questions about commonly advocated methods in special education.

I. HISTORY and BACKGROUND

The Standards are intended as a policy document for professionals in mathematics education as well as a vision of excellence, one which attempts to move the field well beyond the minimal competencies of the back-to-basic movement of the 1980s

While the Standards are the most visible component of math reform for many, particularly special education researchers, it should be noted that they reflect almost two decades of research, curriculum development, and related policy documents by the NCTM and other professional organizations. The research, which draws extensively on cognitive psychology and child development (e.g., Gelman & Gallistel, 1978; Grouws, 1992; Hiebert, 1986; Putnam, Lampert, & Peterson, 1990), is a considerable enhancement of the knowledge base which led to the "New Math" movement of the early 1960s. Mathematics education research over the last ten years has also yielded detailed analyses of elementary and secondary math concepts (Carpenter, Fennema, & Romberg, 1993; Hiebert & Behr, 1988; Leinhardt, Putnam, & Hattrup, 1992). More recently, a series of research-based curricula have emerged (e.g., Everyday Mathematics, Bell, Bell, & Hartfield, 1993). Finally, policy documents such as An Agenda for Action (NCTM, 1980) and Everybody Counts (National Research Council, 1989) consistently argued for significant changes in the role of computational practice and the type of problem solving found in most commercial textbooks, as well as an increased role for technology.

For example, the Standards press for higher student performance through more challenging curriculum: specifically, a greater emphasis on conceptual understanding and having students solve longer, less well-defined problems. Pushing all students to achieve higher academic goals would seem to directly clash with the move to include more and more special education students in general education classrooms where little if any additional support is provided (Carnine, Jones, & Dixon, 1994; Fuchs & Fuchs, 1994). After all, problems accommodating students with learning disabilities in traditional, general education classrooms are well documented in recent case study research (Baker & Zigmond, 1990; Schumm et al., 1995).

Even those special educators who appear more sympathetic to the Standards exhibit difficulty and confusion when attempting to translate the mathematics research of the 1980s into a special education framework. Gersten, Keating, and Irvin (1995), for example, misconstrue constructivist discourse as teacher-directed example selection. 5 Also, traditional cognitive interpretations of student misconceptions in arithmetic are uncritically equated with constructivist theory. Without systematic evaluation, the ways in which current mathematics reform might "play out" for students with learning disabilities or those at risk for special education is likely to remain speculative or only at the level of policy debate. At the very least, such evaluation would help determine whether any problems with innovations in mathematics rest in the nature of the curriculum and pedagogy or the more traditional problem of educating students with learning disabilities in mainstreamed environments.

II. PURPOSE OF THE STUDY

The purpose of this study was to examine the effects of an innovative approach to mathematics instruction on academic performance of mainstreamed students with learning disabilities and academically low achieving students who are at risk for special education. This research was part of an extensive study of teachers in three elementary schools, two of which were in the third year of using a new, university-based math reform curriculum. Nine third grade classrooms were the focus of systematic observations, teacher and student interviews, and academic assessment. Quantitative as well as qualitative data were collected in the attempt to triangulate on the effects of innovative curriculum and teaching techniques on target students (see Patton, 1980). Because of the extent of the data, this report will concentrate on the academic growth of students over the course of the year. Observation and interview data are described elsewhere (see Baxter & Woodward, 1995).

III. METHOD

Teachers and schools. The participants in this study were nine third grade teachers and their students in three schools located in the Pacific Northwest. The two intervention schools were selected because they were using the Everyday Mathematics program (Bell et al., 1993), which is closely aligned with the 1989 NCTM Standards. A third school, which acted as a comparison, was using Heath Mathematics (Rucker, 1988), a more traditional approach to mathematics. Five third grade teachers taught in the two intervention schools and four in the comparison school. The schools were comparable along many variables. All were middle class, suburban elementary schools with similar socio-economic status (determined by the very low number of students on free or reduced lunch), as well as other demographic information provided by the districts. Schools were also comparable in the general beliefs held by the staff regarding mathematics instruction. First through fifth grade teachers at each school completed the Mathematics Beliefs Scale (Fennema, Carpenter, & Loef, 1990), an updated version of the Teacher Belief Scale (Peterson, Fennema, Carpenter, & Loef, 1989). This measure has been used in a number of studies investigating the effects of innovative mathematics instruction.

IV. STUDENTS

A total of 104 third grade students at the two intervention schools participated in this yearlong study. At the comparison school, 101 third graders participated. Forty-four students from the intervention and comparison schools were excluded from the data analysis because they were not present for either the pretesting or posttesting. Twelve students were classified as learning disabled on their IEPs, and they were receiving special education services for mathematics in main streamed settings. Seven students with learning disabilities were in the intervention schools and five were in the comparison school.

It should be noted that interviews with teachers in all three schools indicated that more students could have been referred for special education services in mathematics but were not for a variety of reasons. Some teachers mentioned that the special education teacher primarily served low incidence students (e.g., autistic, students with physical disabilities) or students who had reading problems. There was "little room left" to serve students for math. Three teachers in the intervention schools chose not to refer students, and in two cases, they retained students in the general education classroom for mathematics instruction -- because they did not want to contend with the logistical problems of sending students out for mathematics at important or inconvenient times in the day. These teachers were also skeptical of the quality of mathematics instruction in the special education classroom. They felt that the traditional direct instruction approach to the subject did little to teach students the mathematics they needed for success in future grades.

V. MATERIALS

Intervention schools curriculum. As mentioned earlier, the two intervention schools in this study were using the Everyday Mathematics program. This program reflects over six years of development efforts by mathematics educators at the University of Chicago School Mathematics Project (UCSMP). The project has been funded by grants from the National Science Foundation as well as several major corporations. Initially, program developers translated mathematics textbooks from over 40 countries. Comparative analysis of elementary school texts indicated that the United States had one of the weakest mathematics curricula in the world (Usiskin, 1993). Among the many shortcomings, important mathematical concepts were taught too slowly, tasks surrounding concepts (e.g., measurement, geometry) were too simplistic, and there was too much repetition (Flanders, 1987). To remedy these problems, developers at UCSMP created a curriculum that deemphasized computations and changed the way concepts were reintroduced. For example, when major concepts reappear later in the year or in the next grade level, they are presented in greater depth. This structure is common to Japanese mathematics curricula (Stevenson & Stigler, 1992; Stigler & Baranes, 1988). The UCSMP materials also emphasize innovative forms of problem solving. Unlike traditional math word problems, which are often conducive to a key word approach, problems or "number stories" are taken from the child's everyday world or from life science, geography, and other curriculum areas. The program developers are in strong agreement with other mathematics educators (e.g., Carpenter, 1985) in their view that students come to school with informal and intuitive problem solving abilities. The developers drew on this knowledge as a basis for math student-centered problem solving exercises. In these exercises, students are encouraged to use or develop a variety of number models which display relevant quantities (e.g., total and parts; start, change, end; quantity, quantity, difference) to be manipulated in solving these problems.

Automaticity practice is achieved through the use of math "games." Students roll dice and add or subtract the numbers as a way of practicing math facts. Concepts are also developed through games. For example, two students alternate drawing cards from a deck and place each card in one of eight slots on a board. The goal of the game is to create the largest number eight-digit number. Developers suggest that this activity reinforces an understanding of place value in a game-like context. The Everyday Mathematics program emphasizes a series of important NCTM Standards. Students spend considerable time identifying patterns, estimating, and developing number sense. The are encouraged to come up with multiple solutions for problems. Finally, the students are taught to use an array of math tools and manipulatives (e.g., calculators, scales, measuring devices, unifix cubes), and these materials play an important role in daily lessons.

VI. COMPARISON SCHOOL CURRICULUM

The comparison school used the Heath Mathematics Program., a traditional approach to mathematics. Lessons are structured around a systematic progression from facts to algorithms with separate sections on problem solving. Facts and algorithms are taught through massed practice, and students can be assigned as many as 50 facts and 20 to 30 computational problems at a time. Story problems involve one or two sentences and are generally of one type (i.e., they are directly related to the computational problems studied in the lesson or unit). Unlike the Everyday Mathematics program, there is far less emphasis on mathematical concepts and a much greater focus on computational problems. Teachers in the comparison school often supplemented the Heath program with worksheets containing more facts, computational problems, and occasional math exploration activities.

VII. MEASURES

Two different measures were administered to assess the effects of the intervention. The third grade level (Form G) of the Iowa Test of Basic Skills was used as both a pretest and as a posttest. The norm referenced test has well documented reliability and validity. It is a highly traditional, multiple choice form of assessment which measures computations, concepts, and problem solving skills. The second measure, the Informal Mathematics Assessment (IMA), was an individually administered test of problem solving abilities. The intent of this measure 11 was to examine the problem solving processes or strategies a student used in deriving an answer, as well as the answer itself. In this respect, it is consistent with the call for assessment which is more closely aligned with math reform and the NCTM Standards (Romberg, 1995). Students were also given a range of mathematical tools and representations which they were encouraged to use as part of the problem solving. The IMA "tool kit" included a calculator, ruler, paper and pencil, poker chips, and number squares with ones, tens, and hundreds values. The six items on the test were based on an analysis of third grade mathematics texts, innovative materials which subscribe to the 1989 NCTM Standards as well as more traditional texts. In order to prevent fatigue and possible frustration, particularly with academically low achieving students, the items on the IMA were relatively brief, and the examiner read each one to the student. While the IMA took approximately 15 minutes to administer, students were given as much time as they wanted to complete each item.

VIII. RESULTS AND DISCUSSION

Data for this study were analyzed quantitatively and qualitatively. The quantitative data provided a broad framework for gauging the relative changes in academic performance for students at the intervention and comparison schools. This was particularly important as two different types of academic measures were used to assess growth in mathematics. The protocols from the IMA, along with classroom observations and teacher interviews enabled a qualitative analysis of the effects of the innovative curriculum on students with learning disabilities and academically low achieving students.

A. Discussion

The results of this study suggest that the innovative curriculum benefited the majority of students in the intervention schools. Quasi-experimental comparisons indicated no overall decline in ITBS total test scores for the entire sample. In fact, most intervention students maintained or significantly improved performance levels on ITBS subtests directly related to the design of the intervention curricula (i.e., concepts and problem solving for average and higher ability students). Improved performance was also evident on the IMA alternative assessment, a measure which is more closely aligned with recent reforms in mathematics. Quantitative and qualitative changes on the IMA were particularly evident for average achieving students at the intervention schools. They tended to more closely approximate the behavior of high achieving students in their ability to restate and decompose problems as well as use calculators as an integral part of problem solving. Some mathematics reformers (e.g., Romberg, 1995) may view these findings as highly encouraging insofar as performance at the intervention school was not undercut by a lowering of scores on traditional measures. The findings from the IMA in this study tend to complement overall trends in the ITBS data. As Romberg and other would argue, an innovative form of assessment like the IMA is critical in documenting the varied and more subtle effects of mathematics reform. As for students with learning disabilities and their academically low achieving peers, data from this study indicate only marginal improvement in their learning. Quasi-experimental results even suggest that students at or below the 34th percentile in the comparison school made more dramatic gains in total test performance on the ITBS total test (i.e., from the 20th to 30th percentile versus 24th to 26th percentile) and ITBS Computations subtest than similar students at the intervention schools. Surprisingly, low achieving students in both intervention and comparison schools made impressive gains on the problem solving subtest of the ITBS, at least in terms of percentile change.

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