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ABSTRACT

This report describes the development and evaluation of mathematics activities manuals for grades K-8, correlated with the Tennessee state mathematics curriculum. Seventeen elementary teachers and seven secondary teachers met during January-June 1989 to write draft versions of the manuals and demonstrate activity-based mathematics and manipulatives. During the 1989-90 school year, 113 teachers from 40 Tennessee systems completed the pilot program. The manuals were revised, and approximately 115 of the 139 Tennessee school districts purchased them in large quantities. A critical component was the training of 21 teaching teams to implement the activities in their systems and classrooms. As a result, team members provided inservice training to more than 4,000 individuals. Additionally, manuals have been shipped to 16 states, the District of Columbia, and Canada. Evaluation investigated the possible influence of using the mathematics activities on grade 5-8 students in rural schools. Statistical analysis focused on changes in student achievement and affective response to mathematics. A 12-item instrument was developed to measure student attitudes toward mathematics. Achievement was measured with the Comprehensive Test of Basic Skills, Fourth Edition. Results indicate that the use of mathematics activities helped improve student achievement and affect in project classrooms, and helped blunt the negative influences of gender (principally being female) and risk status (principally low income). Recommendations and limitations of the study are discussed. (LP)

MATHEMATICS ACTIVITIES FOR RURAL CLASSROOMS IN TENNESSEE: DEVELOPMENT, IMPLEMENTATION, AND EVALUATION RESULTS IN GRADES 5-8

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Background

In 1985-1986, a state-wide committee of Tennessee mathematics educators developed the Mathematics Curriculum Frameworks for Grades K-8 and state curriculum guides for each grade. The guide included instructional objectives, associated content synopses, skills, and activities to facilitate the implementation of the Mathematics Curriculum Framework at the local level. The state curriculum was divided into strands. For K-8, the strands were: numeration; operations on whole numbers and integers; fractions and decimals; graphing, probability, and statistics; problem-solving and applications; measurement; geometry; and ratio, proportion, and percent. The last strand did not begin formally until grade 6. Each guide contained the following statements:

> The final "critical factor" is the use of concrete experiences as students learn a new skill at any level. Without the understanding that comes from concrete experiences, the rote learning of skills has little meaning. The transition from concrete to abstract should be a slow, deliberate process, and at all levels, new concepts should be introduced through concrete experiences. (Tennessee Department of Education, vi)

Because of space limitations in the guides, the activities were described in one or two paragraphs. The elementary committee suggested that a separate activity manual be developed for each grade; but there was no state money for the development of the activity manuals. In 1986-1987, as the guides were distributed throughout the state, one comment was repeated: How do we use activities and manipulatives in the classroom?

Draft Versions of the Manuals

In the fall of 1988, the Center of Excellence for Science and Mathematics Education (CESME) at The University of Tennessee at Martin, wrote a proposal for unallocated Eisenhower funds from the State Department of Education. This grant provided for the development of the activity manuals, correlated to the state curriculum.

Seventeen elementary teachers and seven secondary teachers wrote the draft versions of the manuals from January-June, 1989. The teachers met once a week for three hours to write, edit, and discuss the activities. During the writing process, activity-based mathematics and manipulatives were demonstrated. Since the draft version of the *Curriculum and Evaluation Standards for School Mathematics* was available and the final version would be released in March, discussions of the *Standards* occurred during most sessions. The teachers also wrote during the week. After school was out in May and through the month of June, the group worked together every day.

Before the writing began, Sue Boren (Department of Mathematics and Computer Science) and Robert L. Hartshorn (Department of Educational Studies and Associate Director of Research and Evaluation for the CESME) developed a form in which all activities would be written. The original form was clarified and modified by the teachers. The components were: activity name, strand, objectives, prerequisites, materials needed, instructions to the teacher for making the activity, instructions to the teacher for conducting the activity, directions to the students (if applicable), variations, extensions, references, and blackline masters. Each activity was to be written so that a beginning teacher in the first week of school could use the activity.

There is a manual for each grade K-8. The seventh and eighth grade manuals may be used with arithmetic 9 and pre-algebra. The Algebra Manual includes Algebra I and II. The Unified Geometry manual covers only that course. The Advanced Topics Manual includes selected topics from advanced courses beyond Algebra I, II and Unified Geometry.

Each manual contained an introduction which listed the instructional strategies recommended in the *Standards* and described hints for making the activities, such as how to laminate, to make spinners, and to store multiple sets of the same activity. There were appendices for tangram patterns, I *Have . . . Who Has . . .?* cards, concentration cards, and graph paper.

The draft versions of the manuals were mailed to teachers across the state who had agreed to pilot activities during the 1989-1990 school year. Approximately 144 teachers from 43 systems (including two private schools) initially agreed to pilot the manuals during the 1989-1990 school year. By May 30, 1990, 113 teachers from 40 systems (including one private school) completed all parts of the pilot program.

Revision of the Manuals

At the end of February 1990, descriptions and applications for the revision project were mailed to the writers and pilot teachers. A week later the same information was sent to supervisors of instruction, directors of federal projects, and teacher center directors. The total mailed was 450-500. Announcement of the program was run in the March 20th issue of *Mathematical Moments*.

The composition of the revision teams is described below.

Description	Proposed	Actual
Two teachers for each of the grades K-8	18	13
Three teachers each for algebra I and II, unified geometry, and selected topics from the advanced mathematics courses	9	5
Six teachers to complement the teams as necessary	6	2

By the middle of May, it was evident that certain grade levels did not have enough applications to develop workable teams. Follow-up letters were mailed to increase the number of participants for kindergarten, grades 2 and 4-6, and algebra. Calls were made to teachers and supervisors.

There was no team for grade 4 so Boren was responsible for that grade. The other teachers helped to decide the direction of the revisions for grade 4. The actual revisions were made after the project ended.

Implementation of the Manuals

Order forms were mailed to the 139 Tennessee systems in the fall of 1990. Approximately 115 of the 139 systems have purchased the manuals in large quantities. Some systems purchased the manuals with Eisenhower money and provided inservice training.

The inservice training, including making the activities, proved to be a critical component. The publication of the *Curriculum and Evaluation Standards for School Mathematics* by the National Council of Teachers of Mathematics in the spring of 1989 encouraged an activity-based mathematics program for K-12. The CESME wrote an Eisenhower proposal for funding through the Tennessee Higher Education Commission. Through this grant, 21 three-teacher teams were trained in the summer of 1991 to implement the activities in their systems and in their classrooms. Each team was composed of a K-4, 5-8, and 9-12 teacher. For most of the training, the teams were in groups according to grade levels.

The week's training began with a general session in which schedules were reviewed, expectations for the week were explained, and a model lesson plan (see Appendix) based on the *Standards* was described. During that session, the *Curriculum and Evaluation Standards for School Mathematics* and their implications for the project were discussed.

Tennessee teachers had been very negative toward the implementation of calculators. Since the *Standards* said "appropriate calculators should be available to all students at all times" and the manuals did not actually address calculator usage, the workshop leaders decided to introduce calculators into the project. The first evening, each group participated in calculator activities appropriate to grade levels. The K-4 group used a four-function calculator; 5-8, the TI-12 Explorer calculator; 9-12, a scientific calculator and the TI-81 graphing calculator. These calculators were available throughout the project.

The workshop leaders had written or revised the activity manuals. Each leader had more than 10 years teaching experience. They led activities and modeled lessons which incorporated activities as the teaching strategy. The participants had to present an activity from the manuals for the group. The most important part of the project was the making of activities. Each participant left the workshop with approximately 12 activities for inservice programs and classroom use. The instructors found it difficult to keep the participants on task because they were so excited about making the activities!

The availability of resource materials and catalogs allowed the participants to judge the quality and prices of the materials for themselves. As commercial manipulatives were used in the project, the participants could judge the manipulatives for suitable use in their own system. For example, commercial tangrams are expensive, but six tangrams can be cut from one sheet of needlepoint plastic mesh. The mesh comes in several colors. The sheets had been purchased at a local store for K-4 teachers. This group in particular used the sheets for several different ideas.

The system teams had to develop the outlines for inservice plans and the activities. The inservice was to be six hours for each grade level grouping. The team members had to decide which activities to use and to have their teachers make. Supply lists had to be compiled. The team wrote a plan to present to the system contact person for approval. The system was encouraged to continue to use the team as resource people for implementing activity-based mathematics.

Both teams and individuals on the teams have provided inservice to more than 4000 individuals. Because of presentations at regional and national mathematics meetings, manuals have been shipped to 16 states, District of Columbia, and Canada.

Evaluation

The evaluation by the Appalachian Educational Laboratory (AEL) sought to investigate the possible influence of the use of mathematics activities on grade 5-8 students in the classrooms of teachers who agreed to change their instructional routines by incorporating such activities. Students attended predominantly rural schools. Exploratory (post hoc) statistical analysis focused on changes in measures of students' (1) affective response to mathematics and (2) achievement.

CESME and AEL staff collaborated in the development of a research instrument to measure affective changes. The resulting 12-item instrument measured two factors (alpha reliability of about 0.85). Factor 1 concerned students' attitudes towards mathematics (consisting of six items about the usefulness and meaning of mathematics in the world). Factor 2 concerned students' opinions about mathematics (largely consisting of personal views about engagement with mathematics instruction).

Achievement was measured with the Comprehensive Test of Basic Skills, Fourth Edition (Macmillan/McGraw-Hill, 1989). The CTBS/4 was administered to project students as part of the regular Tennessee Comprehensive Assessment Program testing schedule, as both a pre- and post-test measure. Subtest scores used to construct the dependent variables (i.e., gain scores) were (1) mathematics computation, (2) mathematics concepts and applications, (3) mathematics total, and (4) total CTBS/4 battery scores.

Dependent variables for the purposes of this evaluation were affective and achievement gain scores. Affective gain scores were the difference between pre- and post-test 12-item and the two factor scores, computed separately. Achievement gain scores were the difference between pre- and post-test scores, measured in NCE units. For both affective gains and achievement gains, the analysis tested the differences in various group means and included correlation and regression analysis to help determine the unique contribution of teachers' use of mathematics activities to the dependent measures (i.e., affective and achievement gain scores).

Analysis of Changes in Affective Scores

For the subject group as a whole, affective gain scores remained constant. The statistically significant observed decline in opinion (factor 2) scores (negative gain score) was small (i.e., about $\frac{1}{20}$ of a standard deviation). One-way Analysis of Variance, however, showed that total 12-item affective gain scores and attitude (factor 1) gain scores varied significantly by teacher. The range of variation, in practical terms, was quite large--about two standard deviations, such that students of some teachers increased scores by approximately one standard deviation, whereas students of other teachers decreased their scores approximately one standard deviation.

Exploratory regression analyses suggested that use of mathematics activities may account for at least some of the variation of teacher influence on affective gain scores. First, the quality of a teacher's engagement with the activities (measured by the percent of activities used for which project teachers wrote narrative comments) exerts a positive influence on students' affective gain scores, principally through its influence on attitude (factor 1) gain scores. Second, the purpose for which a teacher used activities seems to exert a positive influence on affective gain scores. Percent of activities to introduce topics to students exerts this positive influence principally through its influence on opinion (factor 2) gain scores.

These results remain statistically significant even when pre-test measures (both achievement and affective scores) and ascribed background variables (i.e., sex, risk status, grade, and period) are statistically controlled. That is, the positive influence of using mathematics activities on affective gains exists even when the influence of powerful background variables is statistically removed.

Results of the exploratory regression analyses seem to imply that the use of mathematics activities in these largely rural middle-grade mathematics classrooms served to mitigate the negative influence on mathematics attitudes (factor 1) of being female. Conclusions about causality are not warranted, however.

Analysis of Changes in Achievement Scores

For the project group as a whole, achievement gains are about what would be expected. However, for the group as a whole, observed NCE achievement post-test scores exceeded NCE achievement pre-test scores on all measures. Only NCE total battery post-test scores, however, were higher than the pre-test score at a statistically significant level; observed increases in the three NCE mathematics scores were not, however, statistically significant. Within the subject group, however, considerable variability existed among the NCE achievement gain scores of different groupings of students.

One-way Analysis of Variance showed that all NCE achievement gain scores varied significantly by teacher. In addition, gain scores varied according to other influences, as follows:

- NCE mathematics computation gain scores varied significantly by (1) grade and (2) period;
- NCE mathematics concepts and applications gain scores varied significantly by (1) sex, (2) risk status, (3) grade, and (4) period;
- NCE mathematics total gain scores varied significantly by (1) sex and (2) period; and
- NCE total battery gain scores varied significantly by (1) grade and (2) period.

Two-way Analyses of Variance revealed that some ascribed variables (i.e., sex, risk status, grade, and period) showed significant two-way interaction effects with teacher, as well. Mathematics computation gain scores vary jointly by (1) teacher and sex (direction of difference varies by teacher) and (2) teacher and risk status (direction, again, varies by teacher). Total battery gain scores vary jointly by (1) teacher and sex (direction varying, again, by teacher) and (2) teacher and risk status (varying by teacher, once again).

As with affective gain scores, regression analyses--which statistically removed the influence of powerful background variables--suggested that the use of mathematics activities exerted a statistically significant positive influence on achievement gain scores. In the case of achievement gain scores, the variable that exerted this influence was the average number of activities used by a teacher per class. The effect was observed for both computation and for concepts and applications gain scores. As with affective gain scores, this influence helps to account for some of the variation of gain scores observed in students of different teachers.

Regression analyses may imply that the use of mathematics activities in these largely rural middle grade mathematics classrooms serve to mitigate such negative influences as student risk status and sex. Again, definitive conclusions about causality are not warranted on the basis of exploratory regression analysis.

Implications for Practice

This evaluation suggests that the use of mathematics activities--specifically those implemented in the project classrooms--helped improve student achievement and affect in project classrooms. The various analyses suggest, moreover, that the use of these activities helped blunt the negative influence of gender (principally being female) and risk status (principally low income sufficient to qualify a student to receive free or reduced price meals) among students in project classrooms.

At the same time, these benefits did not accrue to all students, but only to students in the classrooms of some teachers. Three variables associated with the teachers' use of the activities exerted a positive influence, even with the effect of powerful background variables (pre-test scores, gender, risk status, and others). Percent of activities used by a teacher to introduce a topic positively influenced students' affect through its influence on opinions (factor 2 gain scores). A teacher's "engagement" with the activities (reflected in more extensive narrative comments) positively influenced students' affect through its apparent influence on attitudes (factor 1 gain scores). On the other hand, the sheer number of activities used per class positively influenced achievement gain scores.

As exploratory regression analyses suggest, prior affect influences achievement. At the same time, prior achievement influences affect. Improvements in both students' achievement and affect will inevitably influence one another, over time. On the basis of this evaluation, tentative recommendations are ventured, as follows:

- The use of one or two carefully chosen activities per week--principally to introduce topics--seems to offer the best chance of helping students improve their performance in mathematics, in so far as it is possible to judge from the data gathered and the exploratory analyses conducted.
- Teachers should be prepared to "engage" the activities. That is, they should view them as important, useful, and productive for their students. They should reflect on the experience of using them and take a hand in developing and elaborating activities.
- Some teachers who want to use activities could apparently benefit from peer-coaching or other sorts of consistent mentoring from teachers who are successfully "engaging" the activities. Such arrangements obviously require trust, commitment, and release time (at least for mentors or coaches, and ideally for those receiving mentorship as well).

Limitations

The evaluation of student achievement and affect did not employ a control group, but relied on post hoc analyses of subject students and teachers. Data analysis, therefore, most be considered exploratory; results suggest circumstances that require experimental and longitudinal designs for confirmation.

In addition, it should be noted that the apparently influential teacher variables represented averages based on teachers' self-reports. They were not derived from direct observation in each particular classroom. One might hypothesize that the influences suggested by this analysis would appear stronger still if such direct observation could be accomplished in the future. Direct observation might well discover other variables that might better account for the apparent influences found in this evaluation. The question may devolve to the perennial (and difficult to determine) issue of what makes a good teacher good.

One also needs to remember that a certain vision of mathematics learning surrounds this implementation. The use of mathematics activities is part of that vision, but it by no means represents the entire vision. The ultimate goal is to engage students more fully and more often in considering mathematical ideas and participating in mathematical discourse. The use of the *Mathematics Activities Manuals* appears to be a quite reasonable and promising strategy for helping teachers and students advance toward that goal.

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