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Effective teaching practices in middle school mathematics

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Abstract

In recent years, mathematics teaching has become a profession in crisis. The Second International Mathematics Study shows achievement scores in the United States well below the international median in mathematics. Particularly disturbing information from the eighth grade study is the apparent lack of learning that goes on in the eighth grade. Students scored 38 percent on the pretest and 46 percent on the posttest at the end of the academic year (Willoughby, 1987). Since children usually forget a fair amount over the summer, they must have known more than 38 percent at the end of seventh grade.

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In recent years, mathematics teaching has become a profession in crisis. The Second International Mathematics Study shows achievement scores in the United States well below the international median in mathematics. Particularly disturbing information from the eighth grade study is the apparent lack of learning that goes on in the eighth grade. Students scored 38 percent on the pretest and 46 percent on the posttest at the end of the academic year (Willoughby, 1987). Since children usually forget a fair amount over the summer, they must have known more than 38 percent at the end of seventh grade.

The number of secondary mathematics teachers has dwindled, and many who are left in the ranks have questioned their own commitment to teaching. Among the harder questions they have asked themselves as professionals: "Can the teacher really make a difference in the mathematics classroom?" (Driscoll, 1986).

Numerous research studies have shown that the teacher did make a difference in the middle school (6-9) mathematics classroom. No matter how teachers were identified as effective, whether by student achievement, by supervisors' recommendations, or by the testimony of

students and classroom observers, it was evident that there was a difference between effective teachers of mathematics and less effective teachers of mathematics (Becker & Gersten, 1982, Driscoll, 1986, Evertson, Emmer & Brophy, 1980, Evertson, Anderson, Anderson & Brophy, 1980, Good, 1979, 1981, Good, Grouws & Ebmeier, 1983, Hanna and Ryan, 1985).

What were the characteristics of effective mathematics teachers? Teacher attitudes and expectations may have been more important than their knowledge of subject matter (Begle, 1972, Eisenberg, 1977). McConnell (1978) found that algebra teachers who who liked mathematics and were satisfied with teaching as a profession were rated by their students as being clearer and more effective. Students and observers tended to like the same mathematics teachers, and those teachers also tended to produce higher student achievement. The more successful mathematics teachers were rated as being more task oriented, competent, confident, enthusiastic, student oriented and caring (Evertson et al., 1980).

Investigators concerned with the effects of classroom environment on student achievement beliefs

found that there was a marked decline in achievement beliefs as students enter the junior high school (Miller, 1984). Young children believed that increases in effort could actually cause increases in ability, and thus self worth. Young children did not necessarily view poor performance as an indication of low intelligence. By contrast, junior high students understood well the reciprocal nature of ability and effort. A person who worked hard but failed was seen as having less ability. Many junior high school students would rather be categorized as "lazy" than run the risk of trying hard, failing, and being "dumb" (Covington, 1984). Effective teachers planned for success for junior high students, minimized failure, and consistently encouraged student efforts (Driscoll, 1986).

Good (1981) found that teachers tended to behave differently toward high and low achieving students, and students adjusted their own attitudes, expectations, and behavior accordingly. High achievers were given more choice of tasks and more time to complete work if they requested it. Low achieving students were seated further from the teacher, given less eye contact, less

praise, less time to answer questions and less prompting. Less effort and less work was expected of them.

The more effective teachers had higher expectations for their students. They assigned homework more frequently, stated their concern for academic achievement more often, and gave more academic encouragement. A set of firm and positive expectations, kept visible to students, was found to be an essential component of effective teaching (Evertson, et al 1980).

Good classroom management was found to be an essential ingredient in successful junior high mathematics teaching. Brophy (1983) identified four general states of student intellectual and social development that have implications for classroom management:

> "Stage one (Kindergarten through Grades 2-3) Most children were compliant and oriented toward pleasing their teachers, but they had to be socialized into the student role. They required a great deal of formal instruction, not only in rules and expectations, but in classroom procedures and routines.

Stage Two (Grades 2-3 through 5-6) Students had learned most school rules and routines, and most remained oriented toward obeying and pleasing their teachers. Consequently, less time had to be devoted to classroom management.

Stage Three (Grades 5-6 through Grades 9-10) Students entered adolescence and became more oriented toward peers. Many became resentful or at least questioning of authority, and disruptions resulting from attention seeking, humorous remarks, and adolescent horseplay became common. Classroom management was more time consuming. In contrast to stage one, the task facing teachers was motivating and controlling students who knew what to do but were not always willing to do it. The relative quiet and stability of the middle grades gave way to the adjustment problems of adolescence.

Stage Four (After Grades 9-10) Most students were more personally settled and more oriented toward academic learning again. Classroom management required less teacher time and troubles, and classrooms took on a more businesslike, academic focus."

In view of the nature of Stage Three, it was no surprise that good classroom management was shown to be a necessary (but not sufficient) condition for effective mathematics teaching in the junior high school (Good, 1979). Ninth graders rated teachers who were less authoritarian in discipline and class control as being less clear in teaching algebra (McConnell, 1978). More effective teachers allowed a very low level of student talk during individual work time. Students were usually quiet, on-task, and in their assigned seats during class (Sanford, Emmer & Clements, 1986). Classroom management is discussed separately from instruction, but in practice these two key teaching tasks were interdependent in the junior high school studies (Brophy, 1983, District of Columbia Public Schools, 1985, Evertson & Emmer, 1982, Good et al., 1983).

What teachers did to establish a productive classroom climate and to orient students in their first few days of school was an important determinant of classroom management and teaching success in junior high school (Evertson, 1982, Emmer, Evertson & Anderson, 1980). Successful classroom managers spent considerable time in the early weeks introducing rules and

procedures. They monitored student behavior extensively the first three weeks, and when inappropriate behavior occurred, it was dealt with quickly. Less effective teachers tended to ignore disruptive behavior, and as the year progressed, the off-task behavior increased (Brophy, 1983, Evertson, 1982, Evertson and Emmer, 1982).

Even before the school year began, the effective teachers made decisions about curriculum goals, grouping for ability, classroom policies, and grading. This planning took into account the students the teacher would be dealing with that year. The most effective teachers focused on the students' general knowledge about the specific subject matter. This level of understanding became the "beginning point" for the curriculum (Anang, 1982). Achievement gains were maximized when teachers defined instructing students and helping them achieve mastery in the academic curriculum as basic to their roles as teachers (Brophy, 1986).

Although teachers had to plan for students of widely varying ability, secondary mathematics teachers had little time for individualized instruction with 150 students each day. Teachers who were most effective

used whole-class instruction for the concept development part of the lesson. Whole group instruction enabled the teacher to maximize instructional time for all of the students (Brophy, 1986, Good et al., 1983).

Because classroom management was a more difficult task in classrooms with predominantly low ability students, grouping by ability tended to decrease achievement for low ability students. Teachers in a more mixed-ability classroom had more time to provide individual help to low-ability students (Beckerman & Good, 1981). Extreme class heterogeneity, however, is associated with a lessened degree of student cooperation and task engagement (Evertson, 1982).

In their study of 7th and 8th grade mathematics teachers, Evertson, Emmer, and Brophy (1980) found that effective teachers of mathematics planned and structured classroom time differently from less effective mathematics teachers. In their classes, there were few interruptions resulting from failure to bring or prepare a prop, confusion about what to do next, the need to stop and consult the teacher's manual, false starts, or backtracking to present information that should have been presented earlier (Evertson & Emmer, 1982).

Good et al. (1983) found that effective teachers planned daily review to aid in student understanding. In the first lesson phase, teachers reviewed the previous day's learning, communicated lesson rules and expectations, and prepared students for the upcoming lesson's activities. In the review, effective teachers went beyond simply saying "Remember what we did yesterday?" They actually tested student performance by requiring students to verbalize the meaning of concepts and to apply those concepts to problems. Effective teachers attempted to establish a link between the new information and what students already knew (Englert, 1984). Homework was discussed, checked and collected efficiently in the review phase of the lesson. Teacher comments on homework, however, did not always improve student achievement (Austin, 1976, Good et al, 1983).

Effective teachers did not depend on daily review of homework alone: it often concerned only a small portion of the needed prerequisites for a new topic. Good et al. (1983) proposed daily, weekly, and monthly reviews as part of their model for teaching mathematics. The daily reviews concerned the concepts and skills associated with the previous day's lesson and the

homework, while monthly reviews focused on skills and concepts covered since the last monthly review. The aim was to help the students develop a feeling of continuity about the mathematics they were learning, to help them reorganize the material at their own comprehension levels, and to provide systematic practice to promote retention. It was made clear to students that the review was not simply a collection of exercises and problems, but included those topics which were the most important to remember. Before a new topic or unit was begun, an inventory helped the teacher ascertain whether any prerequisite knowledge needed for the new topic was missing. Such a review also helped students to pull together the mathematical ideas they needed for the new topic. For both the teacher and the student, the usefulness of this feedback in promoting achievement was apparent (Good et al. 1983, Suydam, 1984).

Once the review was completed, effective mathematics teachers engaged in goal-setting behaviors that provided an overview of the lesson, including information concerning what was to be learned, what pupils would be doing, and why it was important. In a study of 480 students in the North Chicago schools, it

was found that advanced organizers made a significant difference in student achievement in geometry topics (Lesh, 1976). Smith and Hodgin (1981) presented geometry students lessons with either a high degree of structure or a low degree of structure. Students presented the high structure lesson achieved significantly higher and rated the lessons higher. The degree to which a teacher organizes lessons is a critical dimension of teacher effectiveness (Rosenshine, 1983).

Time spent in learning was a factor in student achievement. The teachers identified as less effective were actively teaching less than a fourth of the period, and students spent more than half of the class in individual seatwork. Miller (1984) found that in the majority of junior high mathematics classes, only the first one fourth to one third of the class was used for whole class instruction. In contrast, the more effective teachers devoted more than half of each period to combined lecture, demonstration, and discussion. They asked more public questions, creating response opportunities, and response opportunities formed a greater proportion of their contacts with students

(Emmer et al, 1980). Increasing the amount of time in teacher-directed activities is called "direct instruction" by Rosenshine (1983) and "active teaching" by Good (1979).

The academic learning time that was most powerfully associated with achievement gains was not "time on task", but time spent being actively taught by the teacher. Greater achievement gains were seen in classes that included frequent lessons in which the teacher presented information and developed concepts through lecture and demonstration, and elaborated this information in the feedback given following responses to recitation or discussion questions. The most effective teachers prepared students for follow-up assignments by giving instructions and working through practice examples, then monitored progress on those assignments, and followed up with appropriate feedback and reteaching when necessary (Brophy, 1986).

Good et al. (1983) described the steps effective mathematics teachers took in lesson development: review, focus upon the development of meaning and comprehension using active demonstration and teacher explanation, assess student comprehension, repeat meaning portion of

the lesson, provide short (one or two question) practice opportunities for students, and move into seatwork when success rate is high.

Clarity (defined as the careful use of vocabulary and explaining the why with the how in solving problems) and showing the continuity of mathematics were the two teacher qualities that correlated most positively with student attitudes (Driscoll, 1986). Comprehension test scores were positively correlated with the ratings of teacher clarity given by the researchers as they observed classes (McConnell, 1978). Ten experimental studies reported a causal relationship between vagueness terms and achievement. Teacher vagueness (using "somehow, somewhat, other, generally, sort of") was negatively related to student achievement (Smith & Hodgin, 1981, Smith, 1985).

In a study of the effects of teachers preparation on student achievement, the technical skill of questioning contributed 32% of the variation in student mathematics achievement (Madike, 1980). Effective teachers asked many questions during class discussions. Most were "lower order" product questions, but "high order" process questions were also fairly common.

Effective teachers continued to provide students with repeated practice opportunities until they were confident of student understanding. Teachers used fewer prompts in this stage, but they did systematically correct errors on all troublesome concepts. When students provided correct responses, the teachers acknowledged their performance through appropriate and contingent praise statements (Brophy, 1982, Englert, 1984).

Junior high teachers were far more likely to call on students before they asked a question. Compared to elementary level teachers, junior high teachers provided students with less evaluative feedback and directed a greater percentage of their praise and criticism at the student's conduct rather than the quality of a student's work (Miller, 1984). Students who participated in programs where teachers were trained in questioning skills had gains in achievement. Effective junior high mathematics teachers asked more public questions and created more response opportunities (Driscoll, 1986).

Researchers found that a great deal of time was wasted when students worked on problems individually. Ineffective teachers (who spent less time in whole-class

presentation and recitation) often assigned seatwork before students were confident of the required process. Confusion led to students demanding increasing amounts of individual help from the teacher. Some teachers spent almost all of their time helping individuals at their seats, while the rest of the class waited idly and impatiently for help. Without adequate presentation of concepts, students were unable to benefit from the new information (Englert, 1984, Sanford and Evertson, 1981).

The role of seatwork is to provide opportunity for successful practice. Effective teachers used only about ten minutes for seatwork in a class period. Frustration was minimal in seatwork activity because the problems students were asked to do were a direct extension of the development part of the lesson.

Alerting students that they would be accountable for their work decreased off-task behavior. Effective teachers made a statement about accountability at the beginning of the seatwork rather than interrupting student concentration later. The more effective teachers collected seatwork (Good et al., 1983, Worsham, 1981).

Delaying the assignment of homework helped to insure that students will do the work at a later point in time, building distributed practice into the program. Research has consistently shown the superiority of distributed practice over mass practice in helping students to master and retain new concepts and skills (Hunter and Breit, 1976). Students assigned both exploratory and review exercises achieved and retained better than the group having exercises related only to the daily topic (Madike, 1980). In a study of low socio^-economic status students, the most effective teachers gave easy assignments the first day, assuring students of initial success in the class and encouraging their efforts (Sanford & Evertson, 1981).

Conclusion

There can be no doubt that the effect of mathematics teachers on students is profound. Teaching and learning mathematics requires human interaction, and it depends on the actions of both teachers and students on many levels. The teacher does not simply feed his or her knowledge to students. Learning depends on the students' reconstruction about what is meant by the teacher, and about what performance gets approval. The

care and planning teachers put into their clarity, their expectations, and their classroom efforts to welcome and generate student input does influence student understanding.

The importance of clarity and of involving students as much as possible is a message that comes from several major research studies. Two recent studies, however, imply that we are far from heeding that message. In the first, a survey of research on patterns of instruction in American mathematics classrooms, the most noticeable patterns, in an overwhelming number of mathematics classrooms, involved a daily routine in which answers were given to the previous day's assignment; the more difficult problems were worked at the board; new material was covered briefly; assignments were given for the next day; and the rest of the period was spent on the homework assignment (Suydam, 1976).

Just as worrisome as patterns of instruction are patterns of student attitudes. Data from the National Assessment of Educational Progress resulted in the following conclusion: "For the 9 year olds, mathematics was the best-liked of five academic subjects; mathematics was the second best-liked subject of the 13

year olds and the least liked subject of the 17 year olds (Carpenter et al., 1981).

It does not have to stay that way. The research provides strong evidence that junior high teachers can and do make a difference in student learning and attitudes in mathematics. Some teachers were more effective than others in presenting mathematics in ways that increased students' comprehension and use of mathematical ideas. Some teachers have been trained in these methods, and have increased their effectiveness (Sparks, 1984). We need more teachers of mathematics to put effective practices to work. Continued research efforts to learn successful strategies are warranted, as are increased efforts to put these findings into practice.

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