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Using Work-Groups in Mathematics Instruction

The potential benefits of work-groups—enhanced motivation and enthusiasm, positive peer interaction, and advanced mathematical thinking—warrant further trials of the format in classrooms, as well as the development of more appropriate materials.

Dissatisfaction with students' performance in mathematics in the U.S. has led to various efforts toward improvement. While some researchers have examined content or instruction, others have turned their attention to classroom organization, calling for more frequent use of small groups during mathematics learning (Gerleman 1987, Slavin and Karweit 1984, Taylor 1989).

Simply increasing small-group instruction, however, is unlikely to make instruction more meaningful (Good and Biddle 1988). For example, in some classrooms small-group work may offer students more opportunity to talk with one another but may lessen the coherence with which mathematics is presented—the teacher may hurriedly introduce a topic because another group needs direction. Or small-group work may even increase the time that students spend on drill and review, if the teacher gives students abundant easy work so he or she will not be interrupted when working with another group. In contrast, in other classrooms small-group instruction may work very well in that both student verbalization and their understanding of mathematics may be enhanced (for example, the use of well-selected curriculum tasks that allow students to work cooperatively on a mathematically significant task).

From a survey two of us helped conduct of 1,509 elementary teachers in 10 districts and 3 states (Good, Grouws, and Mason, in press), we found that teachers frequently group students within their classes into small clusters according to achievement in order to organize instruction to match student needs. We call these homogeneous groups *achievement-groups* because the primary purpose of grouping is to

sort students according to achievement rather than to allow for extensive social interaction. These survey results are consistent with Gerleman's (1987) conclusion that the most common purpose of grouping seems to be to accommodate differences in student achievement, not to introduce new content or change the nature of tasks assigned. In contrast, teachers may form small groups of students within their classes to promote interaction. In these heterogeneous *work-groups*, teachers want students to work cooperatively to promote social and academic outcomes.

To test our belief that there was great variation in the implementation of both types of small-group instruction and to perhaps discover novel uses of both types, we conducted an observational study of 33 teachers (from 21 schools in 3 districts) who were regularly using either achievement-groups or work-groups (Good et al. under review). Observers' ratings indicated that the teachers who used work-groups for part of the period assigned students interesting and complex mathematics tasks to encourage interaction and develop critical thinking skills (see Good et al. [under review] for details). Because few teachers used these groups, it was difficult to generalize from this finding, but our results encouraged us to gather new data from a larger sample of teachers. Thus, in the present study, our intent was to examine how teachers who use work-groups actually employ these formats and to explore, in a preliminary way, the possible advantages and disadvantages of using these groups during mathematics instruction (Good et al. 1989).

Method: Sample and Procedure

We polled more than 400 teachers about their use of work-groups during mathematics instruction and recruited those who reported using groups more than once a week and for half or more of the mathematics period. We drew the sample—15 teachers in 9 elementary schools—from 3 school districts in a large urban metropolitan area, then conducted 63 observations.

To obtain specific information about how students in groups interacted, the observers examined one group intensively during each session.

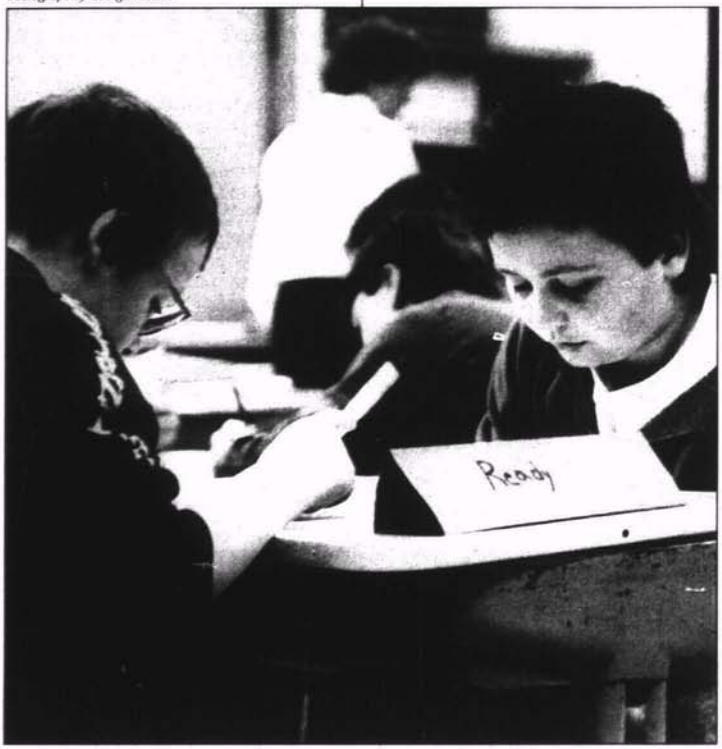
The classroom observers demonstrated more than adequate reliability in collecting descriptive data about the groups. Their procedures included obtaining a script tape of the entire lesson, descriptions of classroom and lesson organization, and a summary of lesson content and focus. They also collected detailed information about each task assigned to students and about how the students interacted, as well as high-inference measures to describe student behavior (for example, degree of positive contribution) and teacher behavior (meaningfulness of development, emphasis on higher-order thinking, and so on). (For more detail on procedures used in developing the observation instrument, observer training, and coding reliability, see Reys and Good 1988).

The script tapes provided a detailed, accurate account of the lesson frameworks (time spent and sequence of teaching/learning activities). To obtain specific information about how students in groups interacted, the observers examined one group intensively during each session. Moreover, all the teachers identified the top five and the bottom five students in their classes, in terms of mathematics achievement. Two randomly selected students, one from each of these groups, served as target students, to be observed espe-

ASCD photograph

The ability to work well with peers and to value the expertise that others bring to a task are beneficial skills that work-groups can help students develop.

Photograph by George Thearle



The more advanced, interesting nature of many mathematical tasks called for in the work-group lessons often motivates students to want to work together to complete them.

cially closely and to be interviewed. During one observation, the observer followed one target student and concentrated on the work-group of which this student became a part. The next observation concentrated on the experience of the other target student. This coding procedure yielded pictures of the class, particular groups, and specific students.

Strengths Observed in Work-Group Lessons

Here we report general impressions of some strengths of the 63 lessons, obtained from independent examination of the lessons and joint discussions among coders and investigators. (For more information on the content and organization of lessons, see Good et al. 1989.)

Active learning. Comparatively more students exchanged mathematical ideas when they were in small work-groups than in achievement-groups. When a task was reasonably well organized, even 2nd graders cooperated to learn and apply mathematical content. Students often had access to materials (geoboards, pattern blocks, dice, and the like) and were encouraged to explore phenomena, manipulate materials, and summarize what they had learned by looking for patterns and making predictions. In such situations, students were generally active, constructive learners.

Interesting mathematics activities. Because most lessons were designed to develop higher-order thinking skills rather than to emphasize computational skills and the quick processing of mathematical information, the group instruction frequently exposed students to important content in an interesting and motivating way. The groups pursued diverse topics, including basic concepts as well as problem solving and estimation, and students were generally highly motivated to work together and complete the assigned task.

Opportunities for peer interaction. Observers' comments about student interaction suggest that many students were developing the ability to work with others and use strengths that others bring to a task—as well as becoming more sensitive to others' needs and interests. However, the extent to which students began to develop these skills and sensitivities varied considerably from classroom to classroom. Even when working in small groups, too many students remained passive.

Enhanced opportunity for mathematical thinking. Work-groups frequently provided students an opportunity to explore diverse and, in some cases, more advanced mathematics. Some groups emphasized understanding concepts that included measurement, geometric relationships, and fractions. In the best examples of work-groups, the combination of students' receiving more interesting,

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challenging mathematical tasks and the opportunity for interaction with peers sometimes led to more advanced mathematical thinking. Although such advanced mathematical discussions did not occur often, the potential for such important student development was amply demonstrated in some work-group settings.

Teacher as curriculum developer. Only during a few observations did teachers use lessons from textbooks or teacher's manuals. In the interviews, several teachers indicated that they frequently altered textbook lessons or substituted their own ideas because the ones in the textbooks did not encourage student cooperation. For example, in one lesson the teacher assigned a few text problems for students to work individually but, in order to generate feedback from peers, grouped students and had them explain and justify their thinking about each problem. Teachers generally analyzed their students' needs and developed appropriate cooperative learning tasks.

Weaknesses Observed in Work-Group Lessons

In examining the study data, we found the following disadvantages to using work-groups during mathematics instruction.

Inadequate curriculum materials. Although we just cited the fact that many teachers developed their own materials as a benefit of small groups, the paucity of curriculum materials designed explicitly for small groups is the greatest hindrance to the effective use of work-groups. Most problems in mathematics textbooks—routine tasks such as review of computational skills—are designed for students to work alone. When such work is presented as a group task, students usually want to work individually. Some invariably conclude, "I could do it faster and better by myself. Why do I have to work with others on these easy tasks?" Such materials also encourage solitary work because students need only ask for assistance when they have a problem and because students generally want to know the correct answer rather than how the problem is solved.

Curriculum discontinuity. When teachers were left to their own devices to develop small-group tasks (taking examples from inservice programs, buying supplementary books, writing their own curriculums), there often was no continuity in content within the class or across grades. Sometimes more sophisticated content, such as multiples and probability, was introduced at lower grades than at higher grades. Moreover, younger students were often required to behave more maturely and to show more self-initiation and self-evaluation than older students. In the interviews, some teachers indicated that lack of continuity was a problem within their own classes. They were not sure how to adapt work-group instruction to all content areas. Several voiced concern that they had not covered all grade-level objectives because small-group work generally focused on higher-order thinking skills, which were not stressed in their curriculum.

Tasks were often not group-dependent. When tasks do not call for students to engage collectively in exploratory behavior, they are not well suited to work-groups. Observers noted that the most effective tasks assigned were group-dependent. For example, the task of solving a problem might be group-dependent because the solution or the solution route is not obvious to any one member of the group. The group members would therefore depend on each other for suggestions about how to begin. On the other hand, the task might be rather straightforward but sufficiently complex or time-consuming so that group members could rely on each other to complete parts of the task and then pool their efforts.

Inadequate pacing of tasks. Because some teachers allowed too little time for groups to work, some students and/or groups didn't even get organized. Other students did not take their tasks seriously because they knew (as they told us in interviews) the teacher would soon intervene. Other teachers gave students so much time that they finished tasks early and engaged in off-task behavior. Further, when teachers eventually drew the groups back together, the members had often forgotten essential information about tasks. We recommend that, over time, groups should learn to work on more complex problems that may take half the period, the entire period, or even several days to finish. Of course, students must simultaneously be taught the skills necessary to work profitably for an entire period on independent projects; for example, how to work effectively in groups,

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evaluate their efforts, and obtain information from peers and the teacher.

Assigning student roles is of questionable value. Some programs apparently recommend that students be assigned roles within groups, but our observations led us to question the value of doing so. In many cases, the designation of students as leaders, recorders, or materials managers seemed artificial. Students tended to switch roles when necessary and, unless the teacher reminded them, often abandoned roles altogether. Further, teachers often spent as much time reminding students of their roles as they did teaching a concept. When students are first introduced to group work, perhaps some information on roles and role-playing is appropriate. However, groups—especially in the intermediate grades—should be encouraged to function autonomously as soon as possible. Teachers need to differentiate between assigned management and instructional roles. By "management roles," we imply ones like recorder or materials distributor; in contrast, by "instructional roles," we mean chief investigator, advisor, and the like. Observers noted that the absence of management roles with younger children was associated with confusion, conflict, and wasted time. Instructional roles had limited value for either younger or older students; they often created problems.

The target students' self-assigned roles were consistent across observations, regardless of the group's composition. For example, a high-ability student who was observed on three different occasions, each time with a different group of students, played the same dominant role in each group. Similarly, although a low-ability student observed on several occasions interacted frequently within the group, he played only a minor role in completing the task.

Student passivity. Although we have stressed the positive social climate that existed for many students, a subset of students was passive during group work. If teachers did not address this problem (for example, by calling on them to summarize group work for the entire class or emphasizing diversity rather than speed of responding), passive students were content to allow other students to do the work.

Lesson structure and accountability. Unfortunately, many sessions did not include a group- or teacher-led summary of important aspects of the task. Students need to discuss what they have learned with the teacher and other students in order to understand and explain the activities they have worked on. Too many lessons, however, ended abruptly without sufficient time to summarize what had been learned. For example, in one session a student suggested an approach to solving a problem that was mathematically correct and, indeed, elegant. The other group members did not immediately understand the logic suggested and therefore resisted the approach. Because there were few opportunities to converse outside the group, this target student never received feedback on his suggestion. At first, when the groups are new, teacher summaries and whole-class discussion seem important to their effectiveness. In time, though, students should be able to assume more responsibility for this end-of-task summary.

Synopsis of Grade 3 Lesson

The grade 3 lesson highlighted three related aspects of 3rd grade number work: generating a list of ways to form sums of 3, 4, 5, and 6; developing a system for recording number sentences; and identifying number patterns. The teacher encouraged the children to find all the different ways of writing 3 as a sum (for example, 1+1+1, 2+1, 3+0). She recorded their responses on the board and noted the number of possibilities.

She then asked them to work in pairs to find all the ways to make sums of 4. The students in the observed work-group began to work individually, but the teacher encouraged them to confer and pool solutions to determine whether they had found all possible solutions. Manipulatives were available for students who wanted to use them. Eventually the teacher wrote all solutions on the board. She encouraged the students to check off their solutions as she wrote them and to add to their lists solutions they did not already have.

Next she asked the students to consider the number 5. Before having students work in groups, she asked for group estimates of how many solutions there would be and recorded them. Students in the observed group began working on their own and, when they had recorded a few solutions, conferred and combined their findings. There was considerable competition among the groups to see who could find the greatest number of possible solutions, and much task-related conversation ensued. The teacher's occasional comments encouraged further exploration, which, in turn, increased enthusiasm and excitement. This time the teacher began the follow-up discussion by asking each group to indicate the "system" it had used to obtain as many solutions as possible. After discussing the different strategies, the class decided that starting with two addend equations and progressing to three-addend equations (and beyond) was the most useful way to proceed. The teacher recorded solutions to the number 5 problem using this same strategy and asked groups to give their solutions. Next she encouraged students (a) to look for and report any patterns they observed in the number of solutions for 3, 4, and 5, and (b) to compare results to their earlier estimations. The class discussed recognized patterns in the recorded solutions.

Finally, the teacher asked the students to work with the number 6 using the strategy discussed earlier. During this discussion (following the recording of solutions), the teacher and students identified patterns. She again drew the children's attention to the number of solutions that were found for 3, 4, 5, and 6. She asked if a pattern was apparent and if they could predict how many solutions the number 7 would provide. The students offered some suggestions but arrived at no conclusion.

The teacher closed the lesson by announcing that she would leave the recorded material on the board for students to examine more closely if they wished to.

Obviously, the effectiveness of a work-group depends on students' mathematical knowledge and their experience in cooperative settings, as well as the teacher's instructional goals.

Synopsis of Grade 5 Lesson

The focus of the 58-minute 5th grade lesson was exploration of equivalent fractions. More than 45 minutes was devoted to small-group work. The teacher began with a brief advance organizer and reminded students that during group work any questions asked must be group, not individual, ones. He then introduced the main lesson content, gave directions about procedures, and assigned roles within groups. He emphasized the need for groups to work together and again discouraged individual questions. The leaders of the various groups collected materials, and the teacher began a non-task-related activity while students moved into their group places.

The students began their first task: to write fractional values for various sets of unifix cubes (each set containing from 1–12 cubes) when six unifix cubes = 1/2 (i.e., 1 cube = 1/12, 2 cubes = 1/6). Their initial conclusion was erroneous, and the teacher intervened briefly to redirect them. Their second attempt again resulted in error, and the observer noted that the students did not understand the mathematics required to solve the problem. The teacher came to the group again, gave explicit directions, and arranged the cubes to represent the correct solution.

The group then started on task 2: solving addition and subtraction problems based on the information recorded in task 1 (e.g., represent 1/3 + 1/4 using the 12 cubes as a unit and find the sum). The students worked cooperatively to solve the problems but arrived at incorrect solutions. The teacher entered the group and helped them work through the first problem. The students still did not understand it. He then began to teach the group, but after having spent 10 minutes with the students, it was obvious that they still did not understand the main concept (e.g., renaming fractions). When the teacher left, the group leader suggested that they split into two groups of two, but they soon began to work as a group of four again. By then most of the groups in the class had finished, whether their solutions were correct or not, and were talking and moving about.

The teacher entered the observed group again to check progress but left after about a minute to handle a disruption elsewhere in the room. The observed group stopped working, turned briefly to talk to the observer, and began making designs with their cubes. The teacher returned to the observed group and showed students how to complete the tasks by assigning simpler but related problems. With his close attention and explicit instructions, the group obtained a solution for one problem but failed to solve a second one. Having spent another five minutes with the group, the teacher left.

The students took about five minutes to move back to their original places, at which time the teacher lectured for five minutes about students' forgetting what they had learned and the fact that some groups were more successful than others. He mentioned each group individually, praised its efforts, and encouraged the students to discuss their difficulties.

Work-Group Lesson Examples

No single lesson reveals all the strengths or weaknesses that we saw across the 63 observed sessions. However, to illustrate how teachers structured work-groups and the effects of structure on students, we now summarize one relatively good lesson and one relatively poor lesson. Obviously, the effectiveness of a work-group depends on students' mathematical knowledge and their experience in cooperative settings, as well as the teacher's instructional goals.

Possibilities. In the grade 3 lesson (see box for a synopsis), group work was carefully planned, a logical progression of exercises that required students to think about the mathematics. The activities called for them to summarize their knowledge, look for patterns, and understand the patterns they were observing. They built on their initial work (trying to find all the different ways of reaching the sum of 3), progressing in a meaningful fashion. For example, after completing the exercise with the number 4—before moving to 5—the teacher asked students to estimate how many patterns they would obtain with a different number.

The teacher stressed appreciation for different solutions. At one point in the lesson, when students attempted to see how many solutions they could come up with, the teacher built upon their work by encouraging them to think about why different solutions would be reached. In essence, students were constructing mathematical understanding and reflecting on mathematics.

Problems. Several problems with group work are evident in the 5th grade lesson (see box for a synopsis). First, because the teacher used too little time to develop mathematical ideas and clarify the task, she therefore placed students into groups prematurely. A brief review of central ideas can sometimes be very useful, and a couple of extra minutes spent providing rich examples, particularly if students provide those examples, can give students valuable background information about tasks.

Despite the teacher's desire to have the groups solve their own problems, she quickly intervened when one group had difficulty working independently. Further, because of the teacher's lengthy involvement with this group, other groups became disruptive and off task. Her inability to overlap and to deal with two or three groups at the same time posed problems.

Unfortunately, at the end of the lesson, the teacher continued to direct activity but did not emphasize key ideas or allow students in some groups to share their progress and insight. The teacher blamed the stu-

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dents because they had forgotten important concepts, and she did not pay attention to group interaction.

The Value of Work-Groups

Our findings led us to conclude that students in work-groups are more active learners and more motivated and enthusiastic about mathematics than students who work in achievement-groups. Further, most lessons we observed focused on higher-order thinking skills rather than on rote practice, and many provided students an opportunity to write or verbalize thoughts.

Despite the generally positive picture, however, our data also reflected several disturbing elements. For example, students often wanted to work independently (no doubt because mathematics has always been presented to them in this way and because they do considerable individual work in other subjects), and it was necessary for teachers to select or design tasks that encourage group interaction. Higher-ability students tended either to control the group or to work alone. Some students were passive, and group activities did not necessarily involve all students in cooperative interplay, although the majority were involved successfully. These findings suggest that teachers must develop other techniques to elicit participation from habitually passive students.

We also saw situations in which students had to develop communication skills *while* learning mathematics cooperatively. Such experiences allowed students to see that other students sometimes conceptualize problems differently or use different methods to solve problems. Some assignments enabled students to discuss mathematics with peers.

Our observations revealed an acute need for more curriculum materials for teachers to use with work-groups and for more curriculum coordination across grades. The more group activities a teacher had seen and used, the better equipped he or she was to modify other activities and develop lessons. Some teachers were skillful in adapting problem-solving activities for work-groups. However, we did not see any work-group lessons in some topics that seem especially appropriate for such lessons; for example, the study of statistics (i.e., data collection, representation, and discussion) in the intermediate grades.

Like any organizational plan, the value of work-groups lies not in the use of the method per se but in the quality of implementation (Good, Mulryan, and McCaslin, in press). Still, we believe that work-groups have advantages sufficient to encourage research that will reveal the type of mathematical content best suited to this format as well as how work-groups can be combined with large-group and individualized instruction to promote greater learning.□

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