Problem Solving Makes Math Scores Soar

Results of a revamped mathematics curriculum in Marion, Indiana, confirm the value of a problem-solving approach.

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The pride and joy of Marion, Indiana, educators is a 40-point jump within just two years in elementary mathematics scores. What brought about this dramatic increase? While several changes were made, the key element was a new curriculum emphasizing problem solving. The program also included use of manipulatives and a specific pacing schedule.

Teaching strategies were designed to reflect the program's four goals of:

1. Meaning and understanding
2. Problem solving
3. Mastery of basic facts and computational methods (within strict time limits)
4. Study of all prescribed units at each grade.

From the pupil perspective, the program shifted from a rule-oriented to a process-oriented curriculum. Current mathematics texts emphasize rules—rules for adding whole numbers, rules for computing area, rules for finding the percent of a number. The Marion project developed sets of interrelated concepts rather than isolated bits of knowledge. This emphasis was most evident in the study of problem solving where heuristic procedures were applied to a broad range of problem types.

Problem Solving Predominates

In this approach, students work in small groups to solve nonroutine problems using five heuristics:

1. Look-for-a-pattern
2. Make-a-list
3. Guess-and-test
4. Draw-a-diagram
5. Break-into-parts

When students learned these general strategies they were able to break out of rule-oriented learning and think for themselves. For example, given a problem like "*A farmer had chickens and rabbits. One day he saw 10 heads and 26 feet. How many rabbits did he see?*" many elementary school students used the guess-and-test strategy.

Besides using the heuristics, students were encouraged to develop other strategies for solving problems. After doing a set of problems in small groups, they met in discussion sessions to compare methods and discuss strategies. This encouraged students to make decisions for themselves, rather than seek only the "right" way. In any set of problems, students might expect to use any operation and any heuristic.

A major weakness in textbooks is classification of problems by types. All the problems following a lesson on multiplication involve use of multiplication. In the Marion project students could not anticipate which operations to use.

Not only was problem solving emphasized throughout the year, but it was the first unit to be taught. Rather than starting the school year with a review of basic facts and skills, students recalled and practiced earlier learnings in the context of problem solving. This was not only more efficient and effective, but also was highly motivating.

New Schedules, Teacher Inservice Debut

Another change was in the use of classroom time. Teachers were made aware that computational topics typically dominate the mathematics curriculum; "computation expands to fill the time available." In Marion, an attempt was made to balance the time devoted to such skills with sufficient time for concept development and problem solving.

The Marion project also developed a definite pacing schedule, and teachers were asked to adhere to it. Teachers usually spend as much time as they think necessary for students to learn a given topic; additional days are given if "needed" for certain subjects. With a fixed schedule, students studied the entire text rather than, as in previous years, completing only two-thirds of the chapters.

Another important feature of the Marion Mathematics Program was extensive teacher inservice. Over a one-year period the following inservice sessions were offered for all 139 teachers in grades K–6:

- A brief awareness to launch the program
- Half-day (released time) sessions to study problem solving and use of manipulatives
- A three-week summer writing session to develop the teacher curriculum guides
- Building-level meetings to introduce the guides, discuss progress, and clarify issues
- Half-day sessions (released time) for primary teachers focusing on use of manipulatives (second year).

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Through these inservice sessions, teachers had the opportunity to discuss and understand the program philosophy, to learn about problem solving and how to teach it, to learn the use of manipulatives, and to learn how to teach computational skills efficiently.

Scores Mark Change

Figure 1 shows the scores on the ITBS (Iowa Test of Basic Skills) for the two years preceding the project and the three years following program implementation. Before changing the curriculum, subtest scores for the intermediate grades (4–6) ranged from the 32nd to the 50th percentiles. After one year of the new program the percentiles ranged from the 59th to the 83rd. Fifth-graders, for example, registered significant gains as percentiles for math totals rose from 43 in 1980 to 73 in 1981. This means that compared to other school systems, Marion students jumped 30 percentile points in one year as a result of these curricular changes. As is evident from Figure 1, scores continued to rise in succeeding years. At the sixth–grade level, students' scores were at the 82nd percentile in 1983, compared with the 41st in 1979.

At the end of the first year, there had been little change in scores at the primary level, so we decided there should be more attention to the use of manipulatives. Inservice sessions on the use of manipulatives, especially Unifix Cubes, were held in the fall of 1981. I also taught demonstration lessons, and teachers were asked to prepare lessons for observation. The test results for 1982 showed a dramatic improvement. By the end of 1983, each grade in the elementary schools was scoring in the 70th or 80th percentile.

For the students with three years in the program (see sixth–grade scores for 1983) the overall math score was in the 82nd percentile. These same students scored in the 16th percentile in 1979!

Gains Evaluated

While supporting the idea of problem solving in mathematics, many teachers feel that there is no time to teach it. "What could we leave out?" they ask. In the Marion Project, teachers really did spend time on problem solving as they devoted nearly one–fourth of the year to teaching it. Specific teaching days were allocated in the curriculum guide, principals monitored the program, and the consultant and assistant superintendent made periodic observations. Even so, computation scores increased at a faster rate than any other subtest score. How can this be explained? As this program was not a carefully controlled research project, we cannot weight the contribution of each of the many program factors (problem solving, pacing, inservice, manipulatives). Nevertheless, a few observations can be noted.

During the problem–solving process students are not learning computational procedures as such, but they are applying the skills they know. Furthermore, students are thinking. Perhaps mathematics becomes more meaningful and understandable. Perhaps computational procedures, often learned in a rote fashion, acquire new meaning and are more easily comprehended. Perhaps students interrelate previously disparate ideas during the problem-solving practice.

Pacing was also a factor in the gains on achievement tests. The pupils encountered more ideas and because of the spiral nature of elementary school curricula, learned the material. Perhaps teachers reflected more deeply on the teaching/learning process after they were presented with new ideas at the inservice sessions.

All of the above speculations are reasonable. It is clear from the test data that students made striking gains in their mathematics proficiency. Schools wishing to raise the mathematics performance of pupils are encouraged to consider the following recommendations:

1. Make a commitment to improve the mathematics program.
2. Plan inservice training for teachers, preferably with released time.
3. Make problem solving the focus of the mathematics curriculum. This is the number one recommendation of the National Council of Teachers of Mathematics.
4. Stress the use of manipulatives in teaching mathematics.
5. Build a pacing schedule that not only prescribes time for problem solving but encourages teachers to present all the material in the text.
6. Spend less time on drill and practice and more time on understanding and reasoning.
7. Design a simple evaluation program to monitor progress.

Marion educators demonstrated that curriculum changes can herald significant improvement in critical areas of learning. □

Figure 1. Mathematics Percentile Scores on the ITBS Before and After Program Implementation

	Before Implementation		After Implementation		
	1979	1980	1981	1982	1983
Grade 2					
Math concepts	20%	35%	44%	62%	71%
Math problems	9	24	31	72	72
Math computation	—	8	17	85	85
Math total	16	18	26	74	74
Grade 3					
Math concepts	31	37	37	57	71
Math problems	23	31	49	74	79
Math computation	—	15	15	56	76
Math total	27	28	37	63	71
Grade 4					
Math concepts	43	50	63	63	69
Math problems	37	37	60	60	67
Math computation	32	41	69	60	69
Math total	40	40	62	62	70
Grade 5					
Math concepts	39	39	71	71	71
Math problems	41	47	70	75	70
Math computation	43	43	72	72	79
Math total	37	43	73	73	73
Grade 6					
Math concepts	47	47	70	77	81
Math problems	34	39	59	68	72
Math computation	46	47	73	83	86
Math total	41	46	68	78	82