Snapshot #34

Promoting Student Mathematics Learning Through A Hands-On And Visual Math Program

Portsmouth Middle School
Portland, Oregon

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Research Findings

New instructional approaches being used by mathematics teachers at Portsmouth Middle School in Portland, Oregon encourage students to construct their own understanding of mathematical concepts rather than to work through textbook drills. To revamp their program, these teachers chose to adopt a visual mathematics curriculum, an approach founded upon practices supported by research.

Drawn from the Northwest Regional Educational Laboratory's *Effective Schooling Practices: A Research Synthesis/1990 Update*, the research-based practices demonstrated in the Portsmouth program at the *classroom* level include:

1.2.1. Instructional Groups Formed in the Classroom Fit Students' Academic and Affective Needs

> e. Small groups are used for instruction and practice in the use of higher-order thinking skills.
>
> g. Peer tutoring and peer evaluation groupings are used to make optimum use of time and to insure that students will receive the assistance they need to learn successfully.

1.3.3. Effective Questioning Techniques are Used to Build Basic and Higher-Level Skills

g. When students' initial responses are inaccurate or incomplete, teachers "stay with" them, probing their understanding and helping them to produce better answers.

1.4.1. There are High Expectations for Student Learning

d. Teachers hold students accountable for completing assignments, turning in work, and participating in classroom discussions.

Effective practices at the *school* level include:

2.3.3. Staff Engage in Ongoing Professional Development and Collegial Learning Activities

f. Skill-building activities are delivered over time, so that staff have the opportunity to practice their new learnings and report outcomes.

g. Staff development activities include opportunities for participants to share ideas and concerns regarding the use of new programs and practices.

h. Ongoing technical assistance is made available to staff as they pursue school improvement activities.

k. Staff members learn from one another through peer observation/feedback and other collegial learning activities.

Situation

Portsmouth Middle School is a large, urban intermediate school within the Portland Public School District in Portland, Oregon. Portland is the largest city in the state, with a school district that serves 54,000 students. There are 18 middle schools in the district, all serving sixth, seventh and eighth graders.

Portsmouth's location just north of city center means that it encompasses a racially diverse inner-city population. Whites comprise the majority of the 550 students in the school. Twenty-five percent of the students are African American, six percent are Asian, four percent are Hispanic, and three percent are American Indian. Forty-one percent of the students qualify for free lunch, and another eight percent are eligible for reduced-price lunches.

Context

Staff interest in using a new approach for teaching mathematics was sparked after one teacher participated in the Middle School Math Project, a National Science Foundation curriculum development project at Portland State University. Additional support for staff development at Portsmouth was funded by QUASAR (Qualitative Understanding: Amplifying Student

Achievement and Reasoning). QUASAR is a Ford Foundation program designed to support and study the implementation of instructional programs in disadvantaged communities.

As participants in QUASAR, all four Portsmouth math teachers received summer training to adopt a visual approach in their mathematics instruction. Student growth in problem solving was also tested by QUASAR researchers.

The philosophy of visual math permeated both the teachers' inservice and the middle school classrooms. This change to a new view of mathematical learning is a journey that began with the teachers themselves experiencing a profound change in their relationship with mathematics. As teachers learned to construct their own solutions to problems, they became aware of the personal nature of learning. Using manipulative materials and sketches to solve problems promoted their confidence in the their own problem-solving strategies. Portsmouth staff realized that a substantive changes in math would not be implemented simply by changing textbooks or by mandate from the administration. A major shift in instructional focus required that teachers develop new skills, behavior and beliefs.

As teachers developed new understandings about math, they became aware that previously they had been "feeding" a set of pre-established procedures to the students and training students to "parrot back" these procedures. That form of instruction was seen as teacher centered. To reorient the instructional process toward being more student centered, teachers needed practice in stepping away from center stage and using class time to focus instead on students' exploration of math concepts.

Staff also realized the needed instructional changes were multifaceted and complex and could not be made without thought and planning. Fortunately, funding from the QUASAR project provided the staff with time to work on a schoolwide approach for mathematics instruction. Changes to be incorporated at the classroom level were determined by the teacher team based on principles of both group consensus and individual freedom. This meant that some instructional practices were used by all teachers, and others were modified to meet the needs of each teacher. These decisions were made in collaborative meetings.

Focus on Curriculum Standards Developed by the National Council of Teachers of Mathematics

The NCTM Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics, 1989) served as the foundation for innovations in math instruction at Portsmouth. At the middle school level, NCTM advocates a concept-driven curriculum that encourages students to communicate with and about mathematics. Engaging students is regarded as the key to motivating them. According to NCTM, learning at this level should engage students both intellectually and physically, so that they become active learners. NCTM recommends that concrete experiences be provided to students to help them grasp abstract, complex concepts. The ideal curriculum should feature problem situations using activities that are tactile, auditory and visual.

USE OF VISUAL EXPLANATIONS

Rather than focusing on arithmetic calculations and repetition of drill and practice, mathematics class time at Portsmouth is an exploration of concepts using visual and hands-on models. Students generate their own mathematical algorithms for such operations as multiplying positive and negative integers or dividing fractions and for calculating surface area. Using the overhead projector, teachers display the use of sketches or manipulatives that students can use to explore these concepts. Teachers demonstrate visual representations of a problem and then encourage students to reason their way through problems. The bulk of class time is devoted to student problem-solving work in cooperative teams. When several teams have devised a solution, students demonstrate their own mathematical reasoning by illustrating their team's solution at the overhead projector.

EMPHASIS ON HOW'S AND WHY'S

The math teachers at Portsmouth have all made conscious choices to emphasize the importance of students' development of their own problem-solving strategies. When each problem is introduced, teachers avoid a pre-set way to solve that type of problem. Instead, teachers encourage students to draw or build a representation of their thinking about the problem. Students use the overhead projector to explain their reasoning on problems. In each math classroom, students illustrate their unique solutions, and these are taped onto blackboards around the room. Teachers repeatedly state that they value the students' thinking and their ability to explain their thinking.

Teachers make a point of not asking students to state the correct answer. Instead, they constantly request that students communicate the process they used to solve the problems. Sometimes the students develop new and novel explanations for a problem, and at other times, their explanations provide the teachers with a better understanding of student misconceptions.

Program Features

COOPERATIVE LEARNING GROUPS

The visual math approach is built upon small group interaction. Seating in all math classes is arranged around working groups of three to five students. Usually, problems are introduced to these groups, and then students work together to sketch out a strategy for problem-solving. Small groups are also asked to take responsibility for the learning of everyone in the group. Periodically, student groups are given a rubric sheet and are asked to rate their own skills and efforts on behalf of their team and the group's ability to work together.

CHANGES IN ASSESSMENT

Math grades are not based upon the number of correct answers a student can generate. In fact, traditional letter grades or numerical tallies of quiz scores are not kept. Instead, all students keep portfolios of their work. Work is reviewed by the teacher, who provides feedback to the students using a rubric that identifies work as exceptional, quality, needing revision or incomplete. Students are expected to redo any work that needs revision.

The portfolio includes not only written explanations of problem solving, but also documentation of times that students explained their thinking to other students. These explanations can happen either at the overheard projector or in small group work. This documentation takes the form of "post-it" notes that students add to their portfolio work to jog their own memories about their successful experiences and their efforts to tackle difficult problems during math class.

PORTFOLIO NIGHT WITH PARENTS

Students are all expected to share their work with their parents at an annual evening meeting. These portfolios include specific descriptions about student effort and mathematical performance. Students prepare for this portfolio night by preparing a summary sheet listing their strengths and areas for improvement.

Students have been taught the importance of demonstrating their work and encouraging each other's work, so they share what they have learned about positive feedback with their parents on portfolio night. For example, in one classroom, several students volunteered to demonstrate visual problem-solving techniques to the parents. Another classroom decorated the room with caricatures mimicking parental positive and negative feedback. Student contributions during portfolio night are written up and added to their portfolios.

JOURNAL WRITING

When students assemble a model of a math problem or sketch a picture, they are called upon to use their own powers of observation and reflection. All students are expected to keep a record of what they are learning in their math journals. A list of journal topics is posted in each classroom. Students are asked to use their journals to:

- Record their experiences solving problems with a group
- Make observations or generalizations
- Participate in class or small group discussions
- Explain their ideas
- Share their thinking at the overhead.

Keeping a journal is difficult for the students at first, but their ability to articulate and reflect on their experience improves over time. Students take responsibility.

Visual Math in Action

Watching one of these math classes unfold is a unique experience. The class began with students plopping themselves down in their cooperative work groups. The teachers quickly distributed the math manipulative materials to be used for the day's work. In a lesson on multiplying with negative integers, the class of seventh grade students received a set of red and black squares to represent positive and negatively signed numbers. The teacher briefly reviewed how to use these squares to represent a multiplication problem. She displayed the use of manipulatives at the overhead.

Then students worked with the colored squares to "solve" a multiplication problem at their own desks. (The solution was not a number, but instead a grid of colored squares). The teacher asked one student to display her grid of colored squares at the overhead and to explain her thinking in reaching this array of squares. As the student gave her explanation to the class, the teacher scanned the room and saw that some of the students have different configurations of black and red squares. A boy with a different "solution" was asked to explain his thinking at the overhead also. Seeing two discrepant solutions caused several students to question some of the premises they had seen demonstrated. These students called out their questions to the student standing at the overhead, and he repeated his explanation. Seeing the confusion, two more students said they could help, and they volunteered to explain how they approached this problem. They took their colored squares to the overhead and explained their thinking to the class.

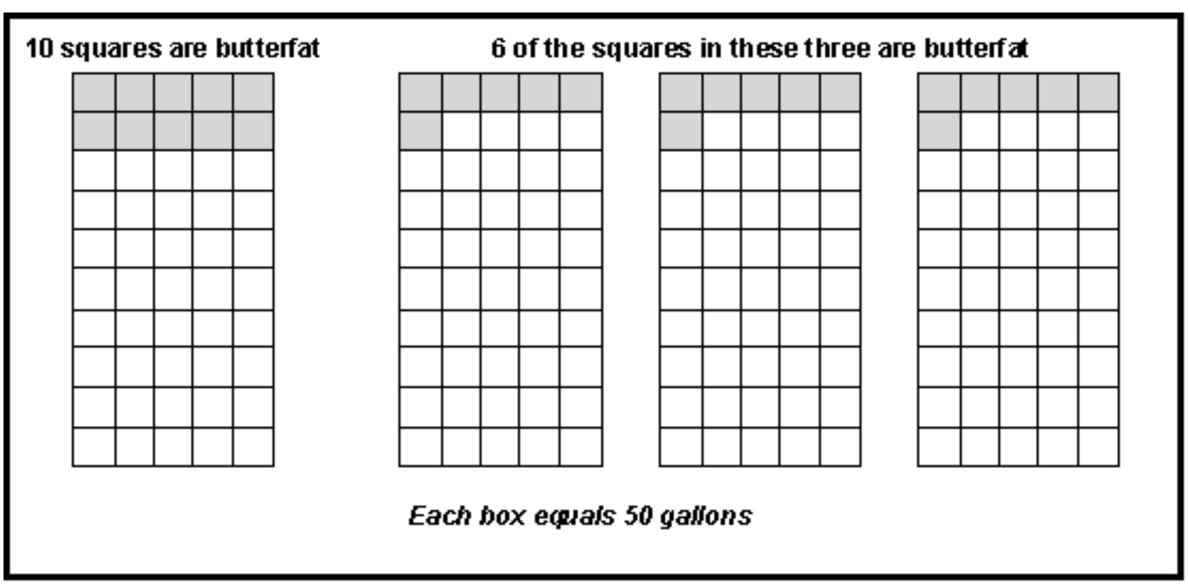
As these students finished their explanations at the overhead, the teacher thanked them for their contributions, but she did not tell any of them that they were right or wrong. Discussing the correctness of a solution process became the responsibility of the class, not of the teacher exclusively. While the teacher did repeat or rephrase a student's question during the explanations at the overhead, she did not end the students' conversations about the problem by giving the class the answer. Instead, she let the students' perturbation drive the discussion. The class as a group reached some agreement on the principles being demonstrated by the manipulatives.

For the next ten minutes of the class, students used their colored squares to display other multiplication problems or, if they were ready to do so, they drew sketches of these on their papers. Students proceeded through these at their own pace but turned to others in their work group to ask questions and get clarification.

In the last few minutes of the class period, students recorded their observations about the lesson in their journals and then re-bagged their materials to drop them into a bin as they filed out of the classroom.

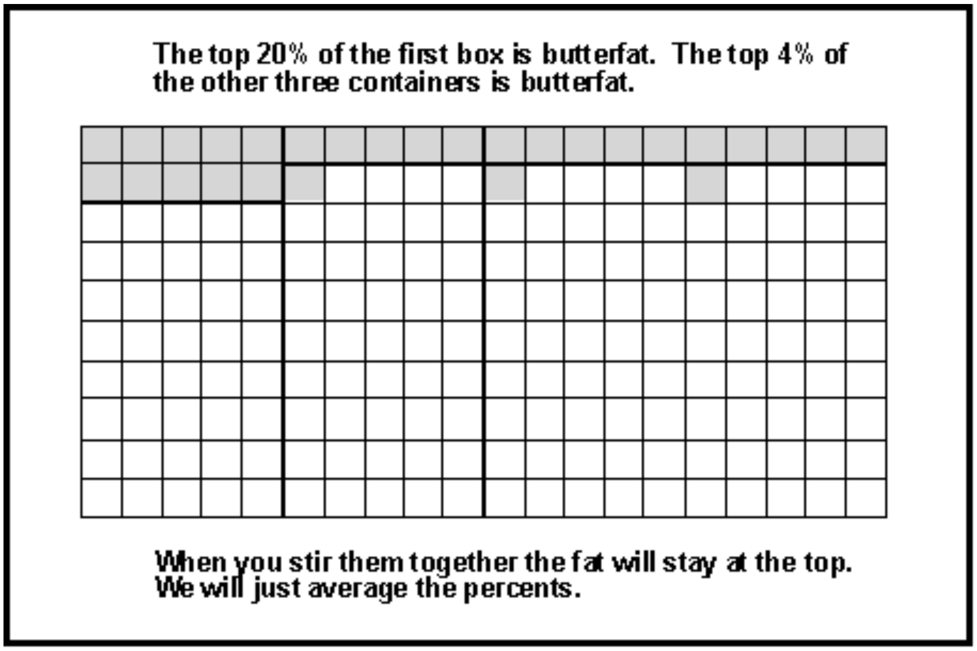
Over time, students internalize some understanding of the math concepts and begin to work with drawings of the problem rather than manipulatives. Later in the school year, two teams in this seventh grade class approached the following problem by sketching visual diagrams of the information in the problem: *If 50 gallons of cream with 20% butterfat is mixed with 150 gallons of milk with 4% butterfat, what percent butterfat is the mixture?*

One of the teams chose to display the 50-gallon and the 150-gallon containers as four 50-gallon boxes. The team chose to draw a grid in each of the boxes to represent the number of gallons and to darken the number of gallons that were butterfat. Once this diagram was drawn, they could actually count the number of gallons of the total mixture that were butterfat and easily calculate the percent.



A second team drew a diagram that demonstrated their knowledge of fluids and talked about how the mixtures would flow together and equalize the butterfat in each of the four containers.

Teams each worked together with one or two students drawing a picture. Student sketches varied groups, with another of the drawings are illustrated depicted below:



The mathematical equation for solving these problems had never been demonstrated to these students. Instead the strategies have been derived from their team discussions and sketches.

Program Concerns and Suggestions for Success

Interviews with Portsmouth teachers revealed their own struggles in making such a dramatic shift in math instruction. Teachers warned that this approach brings with it a certain amount of disequilibrium. One teacher described the process: "We are no longer doing 'cookbook' math. Students are working out their own solutions, and at times they are confused. It is my job to help them understand that disequilibrium is all right. It means that they are struggling and that, in reality, confusion is a condition for real learning."

Teachers also described the reluctance some students have to creating their own mathematical approaches. One teacher recalled that the biggest resistance came from the kids who had been most successful with traditional math. These students were the ones who "had always successfully memorized the rules. These kids had confidence in their math ability. They felt that there was one way to do a problem, and they longed for someone to show them that one way." This teacher went on to say that she had to spend some time reassuring these kids that this approach was harder, but that learning a way to reason out the problem was giving them skills in thinking.

The process of managing hands-on manipulatives can be a logistical challenge to teachers. The Portsmouth teachers emphasized the need for materials to be well organized and accessible. Teachers need appropriate storage bins and resealable plastic bags to hold the materials so they can easily be distributed to groups of students. The teacher needs to develop a system so students can collect and store materials quickly and efficiently at the end of the class period.

Being able to "win" parents over to the program is another necessity. As one teacher reported, "The math we do looks like Greek to most parents. They can't just come in and look at students' papers. They have to experience the process themselves." Teachers feel that Parent Nights are essential. Once parents understand the approach, they often turn from being resistant to being advocates for the approach. Parents sometimes express appreciation that their own understanding of math has been expanded. One parent confided in a teacher that the way he had learned math was "really more appropriate for the 18th century. This math is for the 21st century."

The risk of trying a new approach often raises staff concern that such a dramatic shift in instructional practices might interfere with student learning of basic math skills. The math staff, however, managed to allay initial anxieties and have continued with this approach for three years. Test data collected at the end of this time have demonstrated the effectiveness of the new approach.

Program Effectiveness

There have been significant improvements in three areas: student abilities in problem solving, student placement into high school courses, and student beliefs about mathematics.

Problem-solving skills were assessed by a cognitive assessment instrument administered during the third year of the program. This measurement tool, named the Cognitive Assessment Instrument, was developed by QUASAR. It includes 35 open-ended mathematical tasks and a procedure for focused holistic scoring to assess student responses. Scores for each problem ranged from a zero, which meant that student responses showed no understanding, to a four, which indicated that students' responses and rationale for their answers were both logical and clearly communicated. The instrument was administered in the fall and spring of the same school year to measure student growth. In the fall of 1992, 33 percent of the seventh graders gave high quality responses (scores of 3 or 4) to the majority of the problems. In the spring of 1993, the incidence of high-quality responses increased to 45 percent.

Data were also compiled from a citywide math test given each spring to place eighth grade students into general math, pre-algebra and algebra classes in high school. The percent of students scoring highly enough for placement in the more challenging courses has shown a dramatic increase:

	Percent Admitted to Pre-Algebra	Percent Admitted to Algebra	Total Precent
Spring 1991	38	8	46
Spring 1992	36	16	52
Spring 1993	34	29	63

Students who have been interviewed about this math program described an array of reactions. Some students liked the changes in grading. In interviews, these students said that having access to all of their work in a portfolio lets them know where they stand. They have the chance to review their work and see the improvements they make. Other students said that it has been uncomfortable for them to grade their group work and hard for them to write about themselves.

The teachers reported some dramatic improvements in student skills--both in their ability to work with other students and in their ability to take control of their own learning.

For additional information about this program contact Heather Nelson at Portsmouth Middle School, 5103 North Willis Blvd., Portland, Oregon 97203, (503) 280-5666.

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