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Connecting Reasoning and Writing in Student "How to" Manuals

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ANYONE who has ever purchased a do-it-yourself kit for products such as a birdhouse or swing set and then spent hours putting it together will tell you that following the instructions for assembly in the included manual can be a real exercise in mathematical reasoning. However, the person who really exercised reasoning skills was the person who developed the manual in the first place. We found that having students create how-to manuals is a nice way to blend reasoning and writing in the elementary school classroom while involving them in a stimulating, real-life mathematical task. We successfully incorporated this idea into a five-week summer clinic for elementary school at-risk students and students with learning disabilities.

The how-to manuals that we had each student create were small booklets that listed and illustrated the steps to building a particular product, such as a paper box kite, similar to the structure of real how-to manuals. The main purpose of the exercise was to help the students develop a type of mathematical reasoning called *procedural reasoning.* This reasoning skill involves breaking a process down into smaller, distinct steps; it is consistent with the National Council of Teachers of Mathematics (NCTM) reasoning standards (NCTM 1989) and is a common reasoning skill practiced in such activities as creating a computer program, writing a recipe, or giving someone directions. As students planned, built, and documented their constructions with their manuals, they were also involved in such mathematical activities as measuring with a ruler, making arithmetic calculations, and drawing three-dimensional diagrams.

Since improved student writing was also an important goal for our summer clinic, we carefully organized the learning activities in a process-writing approach. This approach involves students in brainstorming ideas, writing down their ideas, conferring with other students, revising their work, and, finally, publishing their work (Graves 1985; Graves and Hansen 1984). Since the how-to manuals were structured written work expressing the students' reasoning steps, the process-writing approach was a useful way both to organize instruction and to ensure that students were assisted in the writing process. The instructional activities were then broken down into four process-writing phases.

INSTRUCTIONAL ACTIVITIES

Phase 1: Construction

To begin the construction phase, we first led the class in a planning discussion of the dimensions and characteristics of a product model, in this instance a model box kite. Students were asked such questions as "How long is the kite?" and "What is the area of its paper surface?" The students then took turns finding the needed measurements, doing the calculations, and sharing the results with the class. We also asked thought-provoking, science-related questions such as "What makes a real box kite fly?" "What are the differences between your model kite and a real kite?" and "Could you attach the string to anywhere on a real kite?"

After this initial planning discussion, we asked the students to make a box kite similar to a teacher-made model. Since we had students ranging from first to seventh grade, the products we used varied in sophistication from student to student, but all students worked on the same type of product each week, such as a box kite, a box house, and a box space station. Students had access to construction materials that included poster board, glue, plastic straws, and tape, as well as construction tools such as rulers, scissors, and pencils. They also had access to the school library, where they could seek additional information about their product as desired. For instance, several students found it necessary to research whether their box kite needed a tail or not.

All the products used student-created boxes that were made out of 100-square-inch pieces of poster board, which required students first to measure and cut 10-inch-by-10-inch squares from a larger sheet. Additional mathematical concepts were introduced as the squares were folded into boxes. For instance, students investigated the concept of volume by trying to decide which dimensions would produce a box with the largest volume and then tested possibilities with teacher-supplied jelly beans. Students then used their simple boxes to create the more elaborate models of real products, such as a box-kite model, composed of two boxes separated by four sticks (we used soda straws).

Phase 2: Writing

After the students constructed their products, they were asked to record the steps they used to build them. Students sat near their "creations" and remembered the steps they used in constructing them. With paper and pencil, they wrote down their steps in the construction process, with the teacher reminding them periodically that they were writing out the directions so that some other student could also build their product. We also encouraged them to pick up and reexamine their products, or even take them partially apart, to help them remember the steps they had used in the construction process. Many students requested to type out their steps on the word processor so that their directions would be easier for other students to read. Students did a surprising amount of careful writing during this phase, as shown by a fourth-grade student's written steps in figure 14.1.

HOW TO MAKE A BOX KITE

1. Get a big piece of paper.
2. Then draw a big square.
3. Get a ruler.
4. Use the ruler to draw eather a 1-inch 2-inch or 3 inch going down
5. Whatever you pick cut the side of the square to the line.
6. Then you fold up all the sides and tape them.
7. Get 4 straws and tape them in the corners.
8. And make another box and tape the four straws to the corners of the other box.

YOU HAVE A BOX KITE!!!!!!!

Fig. 14.1. A fourth-grade student's written steps that describe how to build a box kite

Phase 3: Revision

Next, the students shared their written steps with at least one other student to help refine their manuals. This peer conferencing allowed students to ask each other such questions as "How long a line?" or "Where did you fold the paper?" The students were very supportive of one another during this activity, and they seemed genuinely curious about what other students had listed for construction steps. After consulting, the students worked on revising their written steps.

Phase 4: Publication

Finally, the students created diagrams to help illustrate their how-to manuals. Many of the students cut apart their written steps and tried to

put a diagram with each step. This resulted in steps that resembled the real-life how-to manuals found in prefabricated kits such as model cars or rockets. A third-grade student's example is shown in figure 14.2.

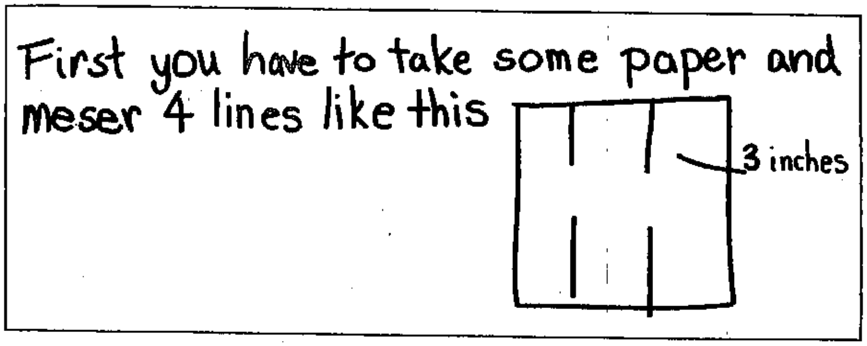

Fig. 14.2. A third-grade student's step mixing text and diagrams

A title page was added, which usually involved a title such as "How to Build a Box Kite" with the student's name listed as the author. Many of the manuals were quite elaborate and used multiple pages of written steps and diagrams. Some students even included diagrams of construction materials and of objects in three dimensions, such as the fourth grader's work shown in figure 14.3.

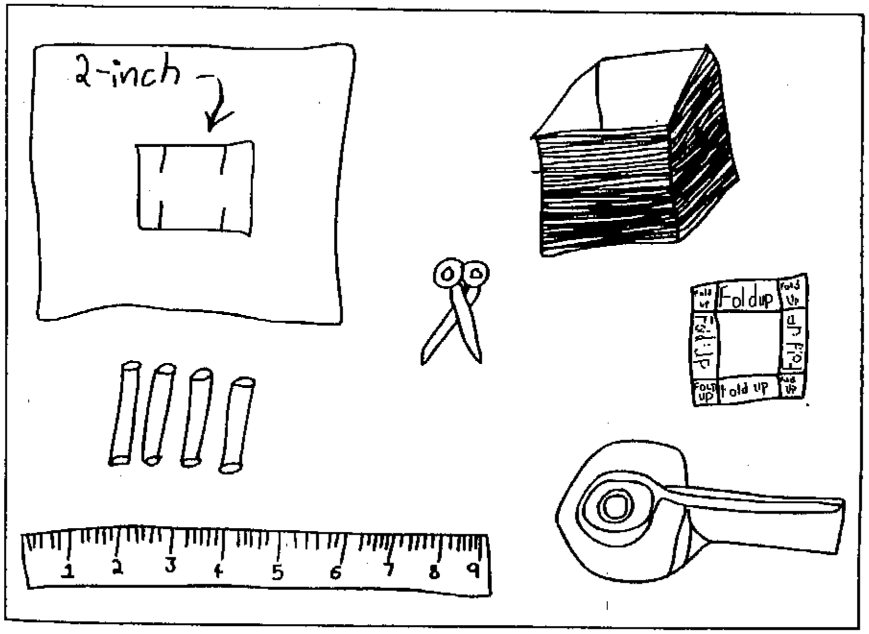

Fig. 14.3. A fourth-grade student's diagram to illustrate the needed construction materials

ASSESSMENT

Assessment was an integral part of the activity. For instance, during the construction phase it was easy to tell which students needed additional instruction in some of the more fundamental skills, such as how to use a ruler. Students themselves also contributed to the ongoing assessment by helping to review and critique the work of other students. The most rewarding assessment, however, came at the end of the four phases when students were encouraged to have other students build a product using their manuals. They found this challenge to be a true test of the accuracy and utility of their work.

THE POWER OF THE "CONSTRUCTION CONNECTION"

In summary, we found that student how-to manuals can produce an enjoyable and natural connection between mathematics and writing in the elementary school classroom. Blending reasoning with writing helps develop both these important skills, and it furnishes the opportunity to apply basic concepts of measurement, arithmetic, and geometry. Science can also be represented, since teachers have the opportunity to ask students thought-provoking questions such as "Why does a box kite fly?" We even found that some important concepts of art, such as perspective drawing, were also represented as students included two- and three-dimensional diagrams in their manuals. We were proud that during the different phases of the summer project our students became, in turn, architects, writers, scientists, and artists as they developed their how-to manuals. Yet the real power of our activities became apparent when we watched these students excitedly share their how-to manuals with one another and with their parents. It seemed that our "construction connection" had helped some youngsters who had become used to failing to gain some real experiences with success in the mathematics classroom.

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