Chapter 5

Virtual Manipulatives in Classroom Research

In this chapter, we discuss several examples of teachers participating in classroom action research using virtual manipulatives. Each example provides background information on the teaching of the lessons using virtual manipulatives, the methods that were used for data collection, brief findings from the classroom research, and how the classroom study informed instruction. The three classroom examples that follow feature classrooms in kindergarten, grade 3, and grade 6.

Studying Virtual Manipulatives in Kindergarten: A Classroom Example

Our first example comes from a classroom study on the topic of patterning that was conducted with a group of 18 kindergarten children in a Title I school, where over half of the students were Limited English Proficiency learners (Moyer, Niezgoda, and Stanley 2005). The children in the kindergarten were very experienced with creating a variety of types of patterns, and the teacher was interested in examining how the representational form (virtual manipulative pattern blocks, wooden pattern blocks, and student drawings) would influence the children's patterning behaviors.

The teacher planned three lessons on patterning for the children over a three-day span. During the first day, children created patterns using the wooden pattern blocks; the second day, they created patterns using the virtual manipulative pattern blocks; on the

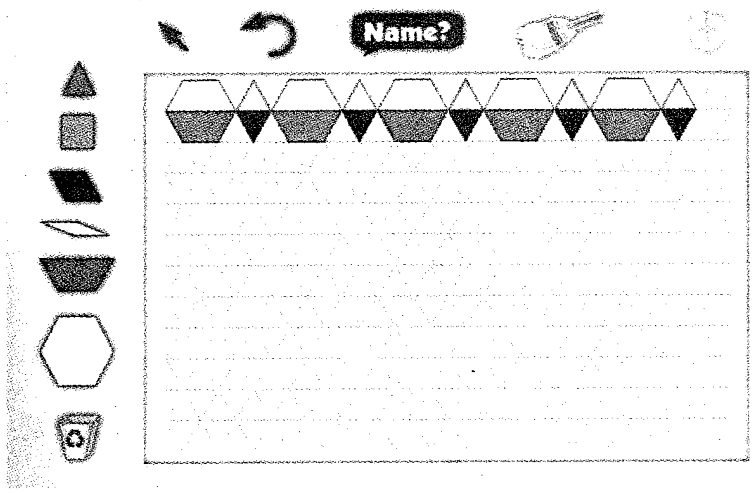

FIGURE 1 *Creative behaviors using the Arcytech applet Pattern Blocks*
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third day, the children created patterns using drawing paper and multicolor markers. During the lessons, five observers recorded information about the patterns the children created by taking notes, drawing examples of the students' work, and printing copies of the children's work from the computer screen. After the three lessons, the teacher and the observers analyzed the children's work by looking at the types of patterns the children created, the number of patterns created, the number of blocks used in the whole pattern and in the pattern stems, and children's creative behaviors. For example, Figure 1 shows a repeating pattern in which the child created a blue triangle by using the green triangle to cover the blue rhombus, which was classified by the research team as a creative behavior.

How Did This Classroom Study Inform Instruction?

By looking at the patterns that the children created using each form of representation, the teacher was able to identify how the use of different representations influenced the patterns the children made. For example, the results showed that the children created a greater number of patterns, they used a greater number of blocks overall and in each pattern stem, and they exhibited more creative behaviors when they used the virtual manipulative pattern blocks (compared to the wooden pattern blocks or to the drawings). However, across each of the different forms of representation, children seemed to lose interest in the particular pattern they were creating once they reached a certain number of blocks or repeats of the pattern (approximately 13–16 blocks). These results showed the teacher that some patterning behaviors were consistent across each representational form. The results also demonstrated differences and advantages among the representations and that, therefore, teachers should choose different representational forms depending on their learning goals for a particular mathematics lesson.

A Classroom Example from Grade 3

In the next classroom study, the research was conducted with two groups of third-grade students learning concepts of addition of fractions and balancing equations (Suh 2005). For the third-grade lessons on fractions, the objectives were to rename fractions, find equivalent fractions, and add and subtract fractions with unlike denominators. Students used the Fraction Equivalent applet found on the National Library of Virtual Manipulatives (http://nlvm.usu.edu/en/nav/vlibrary.html) to explore relationships between equivalent fractions.

On the Fraction Equivalent applet, students were presented with fraction circles and squares with parts shaded, accompanied by the symbolic representation of the fraction, with the following directions: "Find a new name for this fraction by using the arrow buttons to set the number of pieces. Enter the new name and check your answer." Students clicked on arrow buttons below the whole unit, which changed the number of parts, to solve these problems. When students found an equivalent fraction, all lines turned red. When a common denominator was identified, students typed the names of the equivalent fractions into the appropriate boxes. They checked their answers by clicking the Check button. To help students explore relationships among equivalent fractions, the applet prompted students to find several equivalent fractions. This applet was specifically designed to develop the concept of renaming fractions.

Following the lesson on equivalent fractions, the third graders worked with the applet called Adding Fractions, also on the National Library of Virtual Manipulatives. This applet presented fractions with unlike denominators. The applet first prompted students to rename the fractions using the arrow button so that both fractions would have common denominators. Once students successfully renamed the fractions, students proceeded to the next screen to combine the fractions. (See Figure 2.) Students demonstrated significant gains in their knowledge of the algorithmic process for adding fractions with unlike denominators following their use of these virtual manipulative fraction applets.

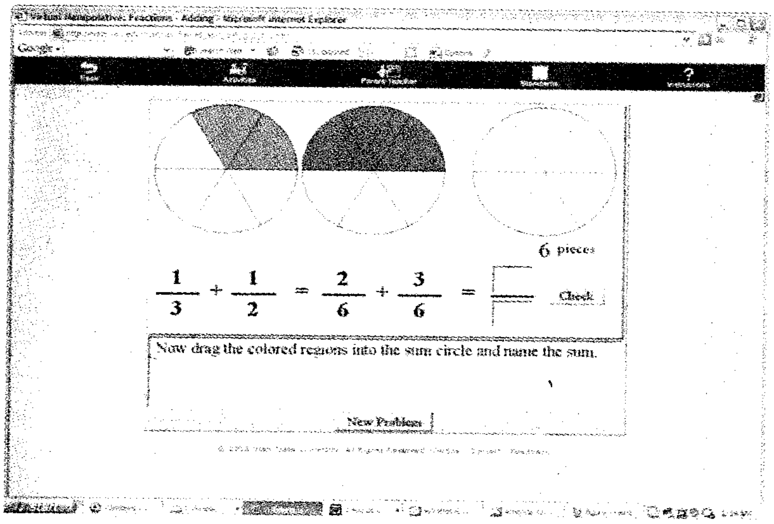

FIGURE 2 *NLVM applet Fractions – Adding*

During the second phase of this classroom study, students in the third grade were introduced to the concept of balancing linear equations using a dynamic algebra balance. During five one-hour class sessions, students used the dynamic algebra scale, which features balanced boxes that represent the unknown *x* and blocks that represent numbers. (See Figure 3.)

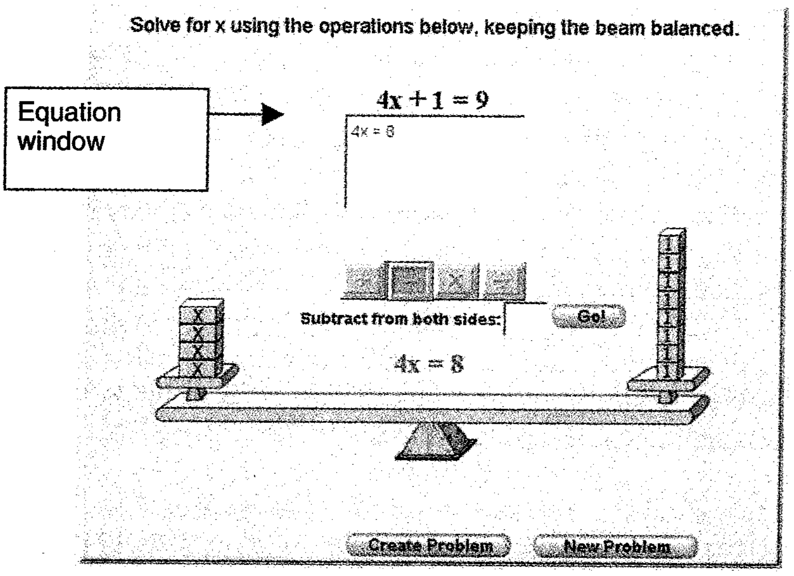

FIGURE 3 *NLVM applet Algebra Balance Scales*

1. After setting up the problem, students clicked on the minus sign and subtracted 1 block from both sides.
2. Once the 1 box disappeared from the screen, students chose the division sign and divided by 4 from each side.
3. Each step taken by the students (algorithm) was displayed in the equation window.

The third-grade students in this study had never been exposed to the concept of linear equations or to the use of a virtual balance scale. The pre- and posttest measures showed significant gains in students' knowledge of the algorithmic process for solving equations. One of the features of the virtual balance scale was that it explicitly linked the dynamic balance scale to the symbolic representation of the algebraic equations that were presented on the scale. When students typed in a symbolic command such as "subtract $3x$ from both sides," the dynamic feature of the applet removed three of the x boxes from both sides of the balance scale and simultaneously displayed a new equation on the screen. The equation window tracked moves made by the student, thereby scaffolding the process of solving for x and explicitly providing the connection between the equations and the actions of the balance scale. During the lessons, three observers collected data using videotaping, mini-interviews while students were working, and copies of students' work on recording sheets.

How Did This Classroom Study Inform Instruction?

There was much to be learned about teaching mathematics using the virtual manipulatives based on the experiences of these third-graders. When students used the Fraction Equivalent and Adding Fraction applets, the teacher noted that they had an opportunity to make sense of the algorithmic processes of combining fractions with unlike denominators. Research shows that students often encounter error patterns of "adding across" when adding fractions with unlike denominators, such as $\frac{1}{3} + \frac{1}{5} = \frac{2}{8}$ where they add the numerators, 1 + 1, and the denominators, 3 + 5 (Ashlock 2006). However, students who worked with the virtual fraction applets successfully renamed the fractions, as was modeled by the virtual fraction applet (e.g., $\frac{3}{4} + \frac{1}{8} = \frac{6}{8} + \frac{1}{8} = \frac{7}{8}$).

When using the virtual algebra balance scale, the teacher noticed that students were keenly aware of the simultaneous actions on the virtual scale and in the equation window. The link between students' actions and the corresponding actions of the onscreen objects and equations made the processes explicit for students.

In addition, the teacher noted that the dynamic capability of the tilting balance scale reinforced the concept of the equal sign, representing the equal sign to mean "the same as," rather than the common misconception of the equal sign meaning "the answer is" or "doing something." In this third-grade study, students' learning was enhanced significantly because they understood the concepts behind the procedures they were performing.

A Classroom Example from Grade 6

In our final example of a classroom study, the research was conducted with a group of 99 sixth-grade students studying operations with integers (Bolyard 2006). Four teachers and six classes of students from two middle schools participated in the study. The purpose of the investigation was to examine student learning outcomes following an instructional unit that used virtual manipulatives as a visual representation of integer addition and subtraction.

The instructional unit took place in four 90-minute sessions. Students explored concepts of integer addition and subtraction through either the context of money (debts and assets) or walking left and right along the number line. Introductory activities focused on establishing the concept of integers in these contexts using number lines and chips. After these introductory activities, students participated in extended computer lab sessions (30 to 40 minutes) in which they used virtual manipulatives representing either the number line or chips to explore addition and subtraction. (See Figures 4 and 5.)

Following each computer session, the teacher led students in follow-up discussions about what they had observed while working with the virtual manipulatives and any conjectures they had made. Students were encouraged to reaffirm and justify their conclusions. To determine changes in knowledge, students completed a pre- and posttest on integer addition and subtraction. In addition, at the end of the unit, a university researcher conducted task-based interviews with nine students. In these interviews, students represented and solved integer addition and subtraction scenarios using pictures, words, and numeric symbols.

How Did This Classroom Study Inform Instruction?

It was evident from the pre- and posttest scores of the students that students' skills in adding and subtracting integers had increased, particularly in the area of subtraction. In this area, pretest scores

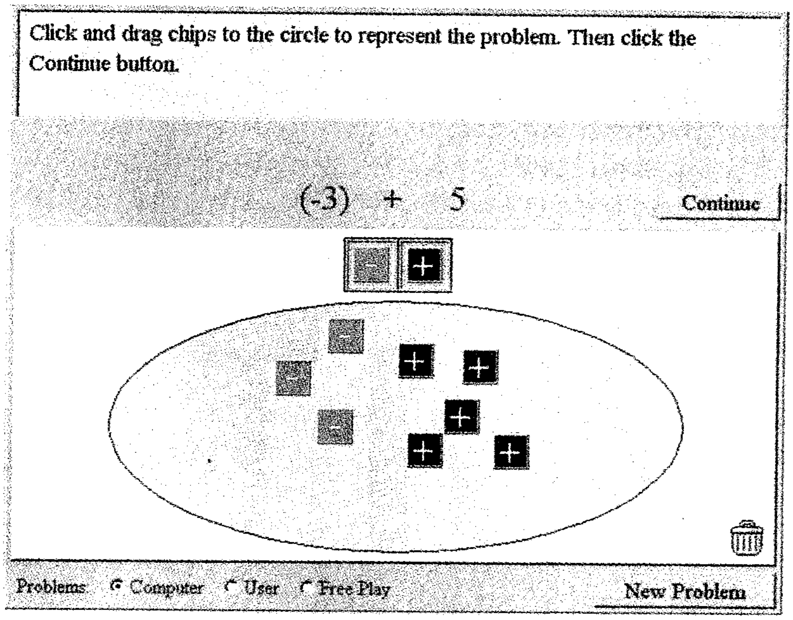

FIGURE 4 *NLVM applet Color Chips – Addition*

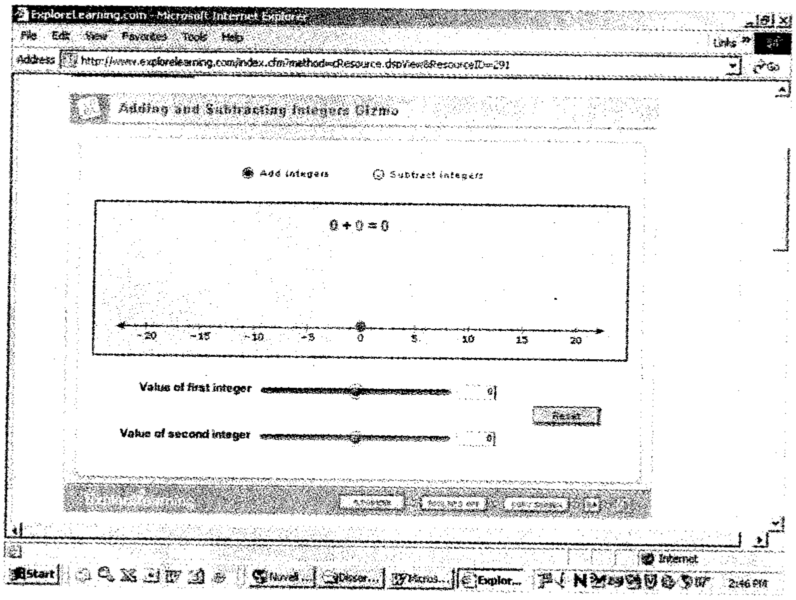

FIGURE 5 *ExploreLearning applet Adding and Subtracting Integers Gizmo*

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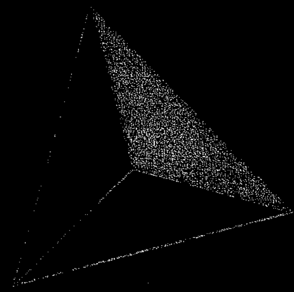

Teaching Mathematics with Virtual Manipulatives

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