TEACHERS’ USES OF VIRTUAL MANIPULATIVES
IN K-8 MATHEMATICS LESSONS

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This study examined teachers’ uses of virtual manipulatives in mathematics lessons across Grades K-8. Ninety-five lessons using virtual manipulatives were analyzed. The content in a majority of the lessons focused on two NCTM (2000) Standards: Number & Operations and Geometry. Virtual geoboards, pattern blocks, base-ten blocks, and tangrams were the applets used most often by teachers. The ways teachers used the virtual manipulatives most frequently focused on students understanding and investigating concepts. It was common for teachers to use the virtual manipulatives alone, or to use physical manipulatives first followed by virtual manipulatives. These results represent the first general exploration of the current use of virtual manipulatives in K-8 classrooms.

The release of the most recent NCTM Standards (2000) gave prominence to representation as a significant area of mathematics education research. Although this was the first appearance of representation as a Standard, teachers have used a variety of representations during mathematics instruction for many years. Representations commonly used in school mathematics include physical or concrete representations, visual or pictorial representations, symbolic or abstract representations, and dynamic electronic representations that combine characteristics of physical and pictorial models (e.g., virtual manipulatives, Moyer, Bolyard, & Spikell, 2002). This study focuses on the examination of teachers’ uses of virtual manipulatives in mathematics lessons across Grades K-8.

Virtual Manipulatives, Representation, and Dual Coding Theory

Goldin (2003) defines representation as a configuration of signs, characters, icons, or objects that stand for, or “represent” something else. Students’ capacity to translate among multiple representational systems influences their abilities to model and understand mathematical constructs (Goldin & Shteingold, 2001). Cognitive science has influenced educational research by proposing theoretical models that explain the encoding of information among representational systems. For example, Dual Coding Theory (DCT), proposed by researchers in the field of educational psychology, is the assumption that information for memory is processed and stored by two interconnected systems and sets of codes (Clark & Paivio, 1991). These sets of codes include visual and verbal codes, which can represent letters, numbers or words. According to DCT, presenting learners with both visual and verbal codes, which are functionally independent, has additive effects on their recall.

A common design structure for virtual manipulative applets is to include verbal codes (i.e., letters, numbers, and words) and visual codes (i.e., pictures) presented simultaneously (Mayer & Anderson, 1992). Applying DCT to instruction when virtual manipulatives are used infers that mathematics environments that activate multiple systems of codes have a greater potential for improving learning because two mental representations are available for use by the learner, rather than just one. Rieber’s (1994) research shows that it is easier for students to recall information from visual processing codes than from verbal codes because visual information is accessed using synchronous processing, rather than sequential processing. Virtual manipulatives (or VMs), which are primarily visually-based tools, can facilitate greater access to memory when students are using this form of visual media.

A recent review of research indicates that students using VMs either alone or in combination with physical manipulatives demonstrate gains in mathematics achievement and understanding (Bolyard, 2006; Moyer, Niezgoda, & Stanley, 2005; Reimer & Moyer, 2005; Suh, 2005; Suh & Moyer, 2007). To focus on teachers’ uses of VMs, we analyzed teachers’ reports of mathematics instruction where these tools were used using the following research question: What VMs are used by teachers in mathematics lessons, and how are they used?

Methods

A total of 116 teachers participated in the study, with two sections at each of four grade bands (K-2, 3-4, 5-6, 7-8), for a total of eight groups. Participants were kindergarten through eighth-grade teachers in eight different teacher professional development institutes taught by four instructors. The eight groups of teachers attended 40-hour summer institutes followed by four formal meetings during the fall and spring of the following academic year (8 hours). The purpose of the professional development was to improve mathematics instruction through readings, discussions, and hands-on experiences. Manipulatives and technology were two major resources used throughout all of the activities and were used daily with each group.

The primary source of data was teacher-developed lesson plans. During the school year, teachers developed and taught mathematics lessons. Researchers collected the written lesson plan reports at the end of the academic year. Teachers’ written plans reported what was actually taught during the lessons in the classrooms. This provided evidence on how the VMs were used. Each of the 116 teachers designed five lessons, for a total of 580 lessons. Of these 580 lessons, 95 lessons used a virtual manipulative (28% Grades K-2, 16% Grades 3-4, 32% Grades 5-6, and 24% Grades 7-8), and these 95 lessons were the focus of this analysis.

Separate analyses examined: (1) the content of the lesson plans, comparing the content with the NCTM Standards (2000); (2) types of VMs used in the lessons within grade-specific groups; (3) categories describing how the VMs were used in the lessons, including (a) investigate (open-ended investigations/problem-solving activities), (b) understand (students developed understandings of specific mathematical concepts through teacher guidance and practice), (c) introduce (teachers introduced new concepts), (d) game (students played games), (e) aide (VMs used for remediation), (f) model (teachers demonstrated concepts, but students did not use VMs), and (g) extend (VMs used to extend concepts for students above grade level); and (4) connections in lessons between virtual and physical manipulatives.

Results

The majority of the virtual manipulative lessons were in the Number & Operations Standard (35%), followed closely by Geometry (32%). A lesser portion of the lessons focused on Algebra (13%), Measurement (13%), and Data Analysis & Probability (7%). Most frequently used of all VMs across the grade levels were virtual geoboards (11% of all lessons), pattern blocks (11%), tangrams (9%) and base-ten blocks (8%). The most frequent use of VMs within grade-specific groups included virtual pattern blocks in 22% and virtual tangrams in 19% of K-2 lessons, virtual base-ten blocks in 20% of 3-4 lessons, and virtual geoboards in 17% of 5-6 lessons and 17% of 7-8 lessons. No virtual manipulative was used by all four grade-specific groups, however eight VMs were used by three of the four grade-specific groups: virtual base-ten blocks, fraction circles, fraction squares, geoboards, geometric solids, number lines, pattern blocks, and tangrams.

As Table 1 shows, how VMs were used focused on investigating mathematical ideas or understanding mathematical concepts (45% and 37%, respectively). There were a greater number of lessons that included open-ended investigations at Grades K-2 (52%) and 5-6 (47%). A greater number of lessons at Grades 3-4 were designed to develop understandings.
(47%), while an equal number of lessons at Grades 7-8 asked students to *investigate* and develop *understandings* (43%).

<table>
<thead>
<tr>
<th>Grade-Specific Groups</th>
<th>K-2 ((N = 27))</th>
<th>3-4 ((N = 15))</th>
<th>5-6 ((N = 30))</th>
<th>7-8 ((N = 23))</th>
<th>All ((N = 95))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigate</td>
<td>14 (52%)</td>
<td>5 (33%)</td>
<td>14 (47%)</td>
<td>10 (43%)</td>
<td>43 (45%)</td>
</tr>
<tr>
<td>Understand</td>
<td>8 (29%)</td>
<td>7 (47%)</td>
<td>10 (33%)</td>
<td>10 (43%)</td>
<td>35 (37%)</td>
</tr>
<tr>
<td>Intro</td>
<td>3 (11%)</td>
<td>3 (20%)</td>
<td>4 (13%)</td>
<td>3 (13%)</td>
<td>13 (14%)</td>
</tr>
<tr>
<td>Game</td>
<td>1 (4%)</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Other (Aide, Model, Extend)</td>
<td>1 (4%)</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
</tr>
</tbody>
</table>

*Note: Because groups contain different Ns, data are presented in numeric and percent formats for comparison purposes.*

**Table 1. How virtual manipulatives were used in the lessons.**

Table 2 shows the relationship of *VMs* with other mathematical tools used in the lessons (e.g., physical manipulatives). An approximate equal number of lessons used *VMs* alone (49 lessons) as used *VMs* together with physical manipulatives (46 lessons). A larger portion of lessons at Grades K-2, 3-4, and 7-8 (59%, 53%, and 52%, respectively) used both *VMs* and physical manipulatives, using the physical materials first, and then using the *VMs* during the second part of the lesson or as an extension. The majority of Grades 5-6 lessons used the *VMs* alone (77%).

<table>
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<th>7-8 ((N = 23))</th>
<th>All ((N = 95))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used Only VM</td>
<td>10 (37%)</td>
<td>6 (40%)</td>
<td>23 (77%)</td>
<td>10 (44%)</td>
<td>49 (52%)</td>
</tr>
<tr>
<td>Used PM, Then VM</td>
<td>16 (59%)</td>
<td>8 (53%)</td>
<td>5 (17%)</td>
<td>12 (52%)</td>
<td>41 (43%)</td>
</tr>
<tr>
<td>Used VM, Then PM</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>2 (7%)</td>
<td>0 (0%)</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Simultaneous Use (VM &amp; PM)</td>
<td>1 (4%)</td>
<td>1 (7%)</td>
<td>0 (0%)</td>
<td>1 (4%)</td>
<td>3 (3%)</td>
</tr>
</tbody>
</table>

*Note: Because groups contain different Ns, data are presented in numeric and percent formats for comparison purposes.*

**Table 2. The relationship of virtual manipulatives with other mathematical tools used in the lessons.**

**Concluding Remarks**

As the results show, there were a variety of *VMs* in use by teachers for mathematics instruction across Grades K through 8. We were not surprised to find that geoboards, pattern blocks, base-ten blocks, and tangrams were the most frequently used *VMs* across the grade levels, as these are commonly used physical manipulatives with which many teachers are familiar. Research examining the benefits of *VMs* at specific grade levels and for specific mathematics content would further inform instructional decision making on the use of these tools in mathematics teaching. (References available upon request.)