Reform agendas have spurred the examination of many aspects of mathematics instruction. With the release of the most recent NCTM Standards (2000), representation gained prominence as an emerging area of research. Although this was the first appearance of representation as a standard, teachers have used a variety of representations in mathematics instruction for many years. Representations commonly used in school mathematics include physical or concrete representations (e.g., manipulatives and geometric models), visual or pictorial representations (such as pictures, graphs, and diagrams), symbolic or abstract representations (such as letters, operation signs, and numerals), and dynamic electronic representations that combine characteristics of physical and pictorial models (i.e., virtual manipulatives; Moyer, Bolyard, & Spikell, 2002). This study examines teachers’ uses of virtual manipulatives in mathematics lessons across Grades K-8.

Theoretical Framework

Tools and models, like virtual manipulatives, are important elements in mathematics teaching and learning as components of representational systems. A recent review of research indicates that students using virtual manipulatives 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, in press), and appear to be more engaged and on task than when using physical manipulatives (Drickey, 2000). Students’ abilities to translate among representations, including internal and external representations, facilitate deeper understanding of mathematical concepts (Goldin, 2003).

Cognitive science has influenced educational research by proposing theoretical models that explain the encoding of information among representational systems. Dual Coding Theory (DCT), proposed by researchers in the field of educational psychology and based on Cognitive Information Processing Theory, 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 codes and verbal codes, which can represent letters, numbers or words. According to DCT, when learners are presented with both visual and verbal codes, which are functionally independent, this has additive effects on their recall. Additionally, Mayer’s (1992) contiguity principle purports that the effectiveness of multimedia instruction increases when verbal codes (i.e., letters, numbers, and words) and visual codes (i.e., pictures) are presented simultaneously, a common element in the design of virtual manipulatives environments.

Applying DCT to instruction infers that the use of 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.

To examine how teachers across Grades K-8 use virtual manipulatives, we analyzed a large collection of lesson plans. This is the first study to conduct a broad examination of current usage of virtual manipulatives for mathematics instruction in Grades K-8.

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 that started during the summer and concluded during the spring of the following year. All teachers worked in the same school system. The length of teaching experience ranged from 1 to 32 years (average =
12 years), with the majority of teachers at the elementary school level (67%) and the remainder at the secondary level (33%).

The primary sources of data in this study were teacher-developed lesson plans. During the academic school year, teacher participants developed and taught mathematics lessons for their classrooms based on learning in the professional development institutes. Written lessons included the following sections: grade level, objectives, materials, procedures, and assessment. In the written lessons, teachers described student activities during the lessons which provided evidence on how the virtual manipulatives were used. Each of the 116 teachers was asked to design five lesson plans, for a total of 580 lessons. Of the total lessons designed, 95 lessons used a virtual manipulative (28% were Grades K-2, 16% were Grades 3-4, 32% were Grades 5-6, and 24% were Grades 7-8) and these lessons were the focus of our analysis.

The first analysis examined the content of the lesson plans, comparing this content with the NCTM Standards (2000). The second analysis determined the type of virtual manipulatives used in the lessons within grade-specific groups. In the third analysis, researchers identified seven categories describing how the mathematical tools were used in the lessons: (a) *investigate* (students engaged in open-ended investigations/problem-solving activities), (b) *understand* (students developed understandings of specific mathematical concepts), (c) *introduce* (teachers introduced new concepts), (d) *game* (students played games), (e) *aide* (virtual manipulatives were used for remediation), (f) *model* (teachers demonstrated concepts, but students did not use the virtual manipulatives), and (g) *extend* (virtual manipulatives were used to extend concepts for students achieving above grade level). In the final analysis, researchers determined whether the virtual manipulatives were used in connection with physical manipulatives.

**Results**

The majority of the virtual manipulative lessons were in the *Number and 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%). Table 1 shows a complete list of the types of virtual manipulatives teachers used in their lesson plans. Most frequently used of all virtual manipulatives 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 virtual manipulatives within grade-specific groups included the virtual pattern blocks in 22% of K-2 lessons, virtual tangrams in 19% of K-2 lessons, and the virtual geoboards in 17% of 5-6 lessons. Other virtual manipulatives were used with less frequency among the grade-specific groups. When the groups were compared, some interesting patterns emerged. No virtual manipulative was used by all four grade-specific groups, however eight virtual manipulatives 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.

Tables 2 and 3 show how virtual manipulatives were used in the lessons. As Table 2 indicates, most of the use of the virtual manipulatives 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% and 43%, respectively). Table 3 shows how virtual manipulatives were used in relation to any physical manipulatives that were used in the lessons. An approximate equal number of lessons used virtual manipulatives alone (49 lessons) as used virtual
manipulatives together with physical manipulatives (46 lessons). A larger portion of lessons at Grades K-2, 3-4, and 7-8 used both virtual manipulatives and physical manipulatives, using the physical materials first, then using the virtual manipulatives in the second part of the lesson or as an extension (59%, 53%, and 52%, respectively). The majority of Grades 5-6 lessons used only virtual manipulatives (77%). *(Tables to be included in the full paper for the proceedings.)*

**Conclusions**

It was not surprising that geoboards, pattern blocks, base-ten blocks, and tangrams were the most frequently used virtual manipulatives across the grade levels, as these are commonly used physical manipulatives with which many teachers may be familiar. While some critics of manipulative use express concerns that teachers using manipulatives are not focusing on the “real math” that students need to learn, in these lessons where virtual manipulatives were used, the teacher rarely planned a “game” as the focus for the use of the virtual manipulatives in the lessons. Rather, virtual manipulative use was focused on students understanding or investigating a concept. About the same number of lessons used virtual manipulatives alone as those that combined the use of virtual and physical manipulatives. These results represent the first general examination of the current use of virtual manipulatives in K-8 classrooms.

**References**


