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The use of virtual and concrete manipulatives in kindergarten school

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This study aimed to explore kindergarten students’ ability in solving symmetry tasks. Specifically, I wanted to investigate how the use of virtual and concrete manipulatives can improve kindergarten students’ (4.5–5.5 years old) ability and representations in symmetry geometry tasks. For this purpose, I used two intervention programmes. In group A (n=25) students used virtual manipulatives and in group B (n=25) concrete manipulatives. Three types of symmetry tasks were used. Analyses of the data showed that both virtual and concrete manipulatives can help students move to a higher level of structural development. Additionally, students improved their ability to a greater extent with the use of virtual manipulatives.

Keywords: Kindergarten, symmetry, virtual manipulatives, concrete manipulatives.

INTRODUCTION

The increased emphasis that has been given to the geometry during the last decades, has changed the content of traditional Euclidean Geometry by introducing new types of geometry (Jones, 2002). According to Sinclair (2008) one of the impacts of Euclid’s Elements in school geometry is that symmetry plays a peripheral role in the curriculum. Furthermore, additional to the mathematical motivations for increased emphasis on symmetry, the psychological research suggests that young children show a strong capacity for attending to and identifying symmetry. According to Vurpillot (1976) the ability to detect symmetry develops early. This strong capacity for attending to and identifying symmetry should be developed through their school geometry experiences (Sinclair & Kaur, 2011). Additionally, the use of technology is growing within schools and gives teachers the opportunity to differentiate their lessons and children’s experiences. Computers are important tools for exploration and discovery of mathematical concepts (Burns & Hamm, 2011). Nevertheless, Burns and Hamm (2011) found little research that supports the use of virtual manipulatives over concrete manipulatives and according to Steen, Brooks and Lyon (2006) research on the impact of virtual manipulatives is limited.

As a result, the purpose of this exploratory study was to investigate kindergarten students’ ability in symmetry tasks as well as the role of virtual and concrete manipulatives in solving the specific tasks. Consequently, the research question addressed in this research is:

How can the use of concrete manipulatives and virtual manipulatives contribute to the understanding of symmetry by kindergarten students?

LITERATURE REVIEW

Students’ understanding of symmetry

Children have intuitive notions of symmetry from early years. As Sarama and Clements (2009) argued, symmetry was the easiest transformation regarding visualization to young students. Additionally, according to Seo and Ginsburg (2004), pre-school children spontaneously constructing symmetrical figures in informal play. Vertical bilateral symmetry remains easier for students to handle than horizontal symmetry (Genkins, 1975) which in turn is easier than diagonal symmetries (Palmer, 1985). While Boulter and Kirby (1994) argued that analytical strategies may lead students into successful answers, Tzekaki and Christodoulou (2000) found that symmetry can be accessed by five and six year old students in a holistic manner. At the same time they found that five and six year old students were able to distinguish symmetrical and non-symmetrical shapes, but on the other hand they were unable to draw symmetrical shapes taking into account their relative position and size.
Virtual and concrete manipulatives

Virtual manipulatives are interactive, web-based virtual representations of dynamic objects that present opportunities for constructing mathematical knowledge. Learners could gain insight into mathematics using visual representations of concepts and relations. Results of available research on virtual manipulatives, offer potentially beneficial uses of technology in mathematics classroom. For example, in a study with two treatments, in order to teach symmetry and congruence, Johnson – Gentile, Clements and Battista (1994) found that Logo-based version enhanced the construction of higher level conceptualizations of motion geometry. Additionally, more recently, Sinclair and Kaur (2011) found that kindergarten children were able to develop an understanding of symmetry that showed awareness of the properties of reflective symmetry through the behaviour of dynamic images.

Even though studies found many perceived benefits on the use of virtual manipulatives, Burns and Hamm (2011) found little research that supports the use of virtual manipulatives over concrete manipulatives. Concrete manipulatives are objects used as tools that allow students to experiment and explore mathematical concepts. Burns and Hamm (2011) found that fourth graders, who were just beginning a unit on symmetry, realized larger pretest–posttest gains when concrete manipulatives were employed.

Theoretical perspectives

In order to analyze the geometric learning of students interacting with virtual and concrete manipulatives I adopted the levels of structural development as proposed by Mulligan, Prescott and Mitchelmore (2003). Young children, who have learned to look for mathematical similarities and differences within and between patterns, will tend to look for similarities and differences in new patterns and broaden their structural understanding accordingly. In contrast, students who tend not to notice salient features of structure are likely to focus on idiosyncratic, non-mathematical features in all situations. Children's representations may classify into the following four broad stages of structural development:

- Stage 1 – Pre-structural stage: Most examples show idiosyncratic features and representations lack any evidence of spatial structure.
- Stage 2 – Emergent (inventive-semiotic) stage: Representations show some relevant elements of the given structure, but their spatial structure is not represented.
- Stage 3 – Partial structural stage: Representations show most relevant aspects of spatial structure, but the representation is incomplete.
- Stage 4 – Stage of structural development: Representations correctly integrate spatial structural features.

METHODOLOGY

The sample of this study consisted of 50 kindergarten students (4.5–5.5 years old) in an urban middle SES district in Cyprus. There were 25 children per class, with a wide range of academic abilities. The method of convenience sampling was used. In group A (n=25) students used virtual manipulatives, while in group B (n=25) students used concrete manipulatives. Firstly, students complete a pre-test in order to determine their initial notions on symmetry. After this, two intervention programmes followed. Students in group A were taught with the use of virtual manipulatives in groups of five students. Nine virtual math applets were used, with three kinds of tasks: recognition of symmetrical and non-symmetrical shapes and images b) positioning axes of symmetry and c) completing shapes and images in order to be symmetrical. The activities used in group B were the same as in group A but in this case students used concrete manipulatives. Equal opportunities were offered to all students to get involved and touch real materials such as geoboards, symmetry mirrors, cardboards, pattern blocks, folding papers.

Each teaching lasted 80 minutes and there were a total of 4 lessons for each group. At the end of the interventions the same test, as the initial, was given to students in order to see if they had an improvement. The test consisted of three parts. Figure 1 presents the three parts of the pre/post-test. Firstly, children were asked to identify symmetrical images and put them in a circle. Secondly children had to put symmetry axes in nine images. Finally, in the third part, children were asked to complete 8 shapes and images in order to be symmetrical. Data were collected in a quiet part of students’ school environment in the form of personal interviews and the interviews were audio-recorded.
Data analysis
Regarding the first part of the test, 0 was given to incorrect answers and 1 point to correct answers. At the second part of the test 0 was given to incorrect answers, 0.5 points to mainly correct answers and 1 point to correct answers. Coding for the third part of the test was based on the classification of representations according to the levels of structural development as proposed by Mulligan, Prescott and Mitchelmore (2003). The analysis of the data was qualitative and quantitative. Due to the limited size of the sample descriptive statistic (means and standard deviations) was used.

RESULTS
Means and standard deviations of pre-test are presented in Table 1. As we can see, the activity where children asked to complete symmetrical shapes have the lowest mean (x̄=0.43, SD=0.23). In addition low performance appears in tasks where children asked to put axes of symmetry. Children seem to perform better in symmetry recognition tasks. As mentioned above, the lowest performance appeared in tasks where children had to complete shapes and images in order to be symmetrical. The most difficult task in this category was task 5 where students asked to complete a symmetrical shape to create a triangle over a horizontal axis of symmetry.

Table 2 presents students' classification of representations in each task according to the level of the structural development. As we can see a large number of students seem to be at stage 1 (pre-structural stage) and stage 2 (emergent structure) since their representations do not present evidence of mathematical structure. Additionally none of students were at stage 4.

Post-test
As we can see in Table 3, after the teaching interventions mean of both groups was increased. Specifically in group A, the mean increased from 0.50 to 0.70 and in group B from 0.53 to 0.60. As it revealed students in group A improved their performance to a greater extent compared with students in group B.
Noticeable seems to be the effect of teaching interventions in the third part of the test. Table 4 and 5 presents the number of students in each stage at pre and post-test.

Students in both groups moved from a lower stage of structural development in a higher level. In group A number of students which categorized at stage 1 and 2 at pre-test was between 19–23 while number of students which categorized at stage 3 and 4 was between 2–6. After the teaching intervention with the use of virtual manipulatives the number of students which categorized at stage 1 and 2 reduced (between 9–15) while the number of students which categorized at stage 3 and 4 increased to 10–16.

Additionally in group B, before the teaching intervention, number of students which categorized at stage 1 and 2 was between 20–23 while number of students categorized at stage 3 and 4 was between 2–5. After the teaching intervention the number of students categorized at stage 1 and 2 reduced to 13–20 while the number of students categorized at stage 3 and 4 increased to 5–12.

As we can see, students in group A increased their ability in completing symmetrical shapes to a greater extent than students in group B.

**Qualitative data analysis**

Through a qualitative analysis of the pre-test we can see some difficulties that students faced. Firstly in the first part of the test students ignored some aspects of the original shapes, which determined whether a shape was symmetrical or not, in at least one image. In the second part of the test, where students asked to put axes of symmetry, students were able to put vertical axes of symmetry but unable to put horizontal axes. Additionally only 2 of them were able to understand that shapes may have more than one axes of symmetry. In the third part, a large number of students at pre-test, transferred the initial shape in at least one task. Furthermore, they ignored some aspects of the original shapes. For example in task 2...

### Table 3: Means and standard deviations for group A and group B

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th></th>
<th>Group B</th>
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<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Pre-test</td>
</tr>
<tr>
<td>Number of Students</td>
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<td>25</td>
<td>25</td>
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<tr>
<td>Mean</td>
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<td>0.70</td>
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<tr>
<td>Standard Deviation</td>
<td>0.20</td>
<td>0.13</td>
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</table>

### Table 4: Students' classification of representations on each task: Group A

<table>
<thead>
<tr>
<th>Tasks 1</th>
<th>Task 2</th>
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<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
<th>Task 8</th>
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<tbody>
<tr>
<td>Pre</td>
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<td>Pre</td>
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<td>11</td>
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<td>9</td>
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<td>11</td>
<td>5</td>
<td>8</td>
<td>4</td>
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<tr>
<td>Stage 4</td>
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<td>2</td>
<td>0</td>
<td>3</td>
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</table>

### Table 5: Students' classification of representations on each task: Group B

<table>
<thead>
<tr>
<th>Tasks 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
<th>Task 8</th>
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<tbody>
<tr>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
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<tr>
<td>Stage 1</td>
<td>8</td>
<td>4</td>
<td>13</td>
<td>7</td>
<td>12</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Stage 2</td>
<td>14</td>
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<td>0</td>
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and 8 they ignored the empty square. At the same time in tasks 4 and 5 students ignored the diagonal line segment that they had to bring in order to complete the symmetrical triangle. At the same time, a large number of students seem to ignore the relative size and position of original shapes.

The qualitative analysis of the post-test showed that the biggest improvement was achieved by a girl in group A. During the intervention Maria faced many difficulties. Originally, she completely ignored the instructions and as she said, she was just trying to make images “to look good.” In another attempt to complete the shapes, she ignored the initial position and the size of the shapes. However, at the end of those activities, she was able to complete symmetrical shapes with vertical and horizontal axes. In addition to this she was able to take into account the initial position and size of most shapes. In Figure 1 we can clearly see an example of Maria’s improvement.

As we can see in Figure 2, at pre-test, Maria transferred all initial shapes. Most of her representations were categorized at the pre-structural stage. However, after the teaching intervention, Maria’s representations improved significantly. In tasks 1, 2, 7 and 8 Maria’s representations manage to reach the stage of partial structure. In tasks 3, 5 and 6, Maria’s representations were classified at emergent structure stage.

The use of virtual manipulatives generated enthusiasm and motivated most of the students. For example John, a boy from group A, set more difficult tasks for himself. During an activity called “Creating Symmetrical Pizzas” John tried to complete a pizza (Figure 3) with a diagonal axis of symmetry even though he was not successful at it.

John seemed to understand those activities from the very beginning. He was able to complete more complicated shapes with vertical and horizontal axes of symmetry without facing particular difficulties. Figure below presents two examples of John’s activities.

John seemed to adopt an analytical strategy in order to complete those activities.
Researcher: Can you tell me the way you think in order to complete this shape?

John: First, I count how many squares are painted on the one side... at this line... 1, 2, 3... 4. So, on the other side I should put 4 squares. I have to put them next to the black line.

Researcher: Why you have to put those squares next to the black line (axis of symmetry)?

John: Well, since in the given example the first square is next to the black line, I strongly believe that I have to put another square to the other side right here (next to the black line). So when I have to fold this picture (he joined his hands and fold them) I am trying to imagine if the one side touch the other side. I remember the video we saw with the butterfly when the one side touches the other after we fold the picture.

CONCLUSIONS

As it revealed from the data analysis, kindergarten students had higher performance in identification of symmetrical images and lower performance in tasks where they had to put axes of symmetry and complete symmetrical shapes. These findings seem to be agreed with previous findings (Sarama & Clements, 2009; Tzekaki & Christodoulou, 2000). According to Tzekaki and Christodoulou (2000) kindergarten students, seem to access symmetry concept in a holistic manner. This is something that is confirmed in this study. During recognition activities, students ignored important details which determine if a shape is symmetrical or not. As a result, they made wrong recognitions. In the third part, most of the students transferred the original shapes and this is something that supports the holistic manner that students faced symmetry concepts. Additionally our findings seem to be in agreement with Genkins (1975) who argued that vertical bilateral symmetry remains easier for students to handle than horizontal symmetry since students at this study faced difficulties in putting horizontal axes of symmetry. As Tzekaki and Christodoulou (2000) argued children of 5 and 6 years old were unable to draw symmetrical shapes taking into account the relative position and size of shapes. This is something that is confirmed in our study since a large number of students from both groups were categorized at pre-structural stage and emergent structural stage according to Mulligan, Prescott and Mitchelmore’s (2003) classification.

Even though both teachings improved students ability in symmetry, the results of our investigation, suggest that the use of virtual manipulatives can improve students’ performance to a greater extent than the use of concrete manipulatives. As Yerushalmy (2005) argued computers may provide representations that are just as personally meaningful to students as physical objects. These results seems to be in agreement with Sinclair and Kaur’s (2011) findings who found that kindergarten children were able to develop an understanding of symmetry that showed awareness of the properties of reflectional symmetry through the behaviour of dynamic images. At the end of the computer session, students in group A were able to recognize symmetrical and non-symmetrical shapes and images, to place axes of symmetry and to complete shapes and images. The number of students which classified at stage 1 and 2 reduced after the teaching intervention with the use of virtual manipulatives. Additionally, more students from group A moved to stage 3 and 4 according to Mulligan, Prescott and Mitchelmore’s (2003) classification of representations. Char (1989) argued that a computer environment offered students greater control and flexibility comparing with the concrete materials. The flexibility of computer manipulatives allowed students to mirror mental “actions on objects” better than concrete manipulatives do and probably this is the reasons for the better students’ performance in group A.

The results reported in this paper should, however, be interpreted with some caution. This study suffers from some limitations. First of all it is a study with small sample, so it is difficult to draw firm conclusions or to generalize the findings to other students or context. Also another limitation of our study is the limited time horizon. This study measured the impact of virtual manipulatives on a short term. As a result the real impact of virtual manipulatives may not become apparent during this short term. As a consequence we can see multiple directions for follow-up research. For example further research is needed to analyze the impact of virtual manipulatives with the use of high level statistical analysis, in large scale studies. These studies should also measure the impact of virtual manipulatives on a long term. Additionally another direction for future research consists of examining
the applications of more recent technologies in kindergarten students such as touch screens.

REFERENCES


