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Zeynel Kablan

Educational Sciences, Kocaeli University, Kocaeli, Turkey

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The effect of manipulatives on mathematics achievement across different learning styles

Zeynel Kablan*

Educational Sciences, Kocaeli University, Kocaeli, Turkey

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The current study investigates the influence of manipulatives used in combination with traditional approaches to mathematics education and how varying amounts of time spent on manipulative use influence student achievement across different learning styles. Three learning environments were created that incorporated varying proportions of traditional teaching approaches and manipulative methods. In one of the learning environments, the teacher used strictly lecture- and exercise-based teaching activities, which are more conducive to abstract learning. Abstract learners showed higher academic performance compared with concrete learners in the environment where only traditional methods were used. For the other two environments, which utilised varying combinations of manipulative tools and traditional methods, the differences in the mathematics achievement levels among students of varying learning styles were not statistically significant. The study also showed that concrete learners demonstrated higher performance in mathematics when manipulatives were used than did their counterparts in the environment where only abstract activities were used; however, in the third learning environment, increasing the amount of manipulative use did not provide an extra benefit to concrete learners.

Keywords: learning environment; manipulative; concrete instruction; abstract instruction; mathematics teaching; Kolb’s learning styles

Introduction

Learning styles are individual characteristics that describe a person’s preferences in a learning environment, and students’ learning styles significantly influence their academic achievement (Biçer, 2010; Cheng, Cheng, & Chen, 2012; JilardiDamavandi, Mahyuddin, Elias, Daud, & Shabani, 2011; Kablan & Kaya, 2013; Kurbal, 2011; Özkan, Sungur, & Tekkaya, 2004). Studies on learning styles have highlighted that different teaching methods have varying effects on student academic performance in students who have different learning styles (Davies, Rutledge, & Davies, 1997; Kvan & Jia, 2005; Tulbure, 2011). In mathematics education, traditional teaching strategies such as lecturing are commonly used (Dana-Picard, Kidron, Komar, & Steiner, 2006). However, traditional teaching strategies do not always accommodate all learning styles (White, 2012). Hence, educators highlight the importance of tailoring instruction to fit students’ learning styles (Bhatti & Bart, 2013). Davies and colleagues (1997) state that to meet the needs of students with different learning styles when teaching, it is essential to incorporate different learning methods into mathematics...
education. There is a need for further exploring the effects of different teaching strategies on students with different learning styles in mathematics. This study investigates the influence of concrete experience (CE) and traditional strategies on the mathematics achievement of students with different learning styles. One of the prominent theories that explain the relationship between learning styles and academic achievement is David Kolb’s Experiential Learning Theory (ELT) (Kolb, 1984).

In Kolb’s ELT, there are four modes of effective learning: CE, reflective observation (RO), abstract conceptualisation (AC) and active experimentation (AE). Kolb stated that an individual’s learning style is determined by the combination of the four learning modes that a person prefers and that each mode is divided into one of two dimensions. The first dimension (AC-CE), also known as the abstract-concrete dimension, reflects how we perceive and comprehend new information. When presented with new situations, some people prefer to respond using concrete methods that engage their feelings and senses, while others prefer abstract methods that involve thinking and analysing. The second dimension (AE-RO), the active-reflective continuum, addresses how we process new information. Some people prefer to transform new information reflectively through observation, while others prefer active involvement by doing (Kolb, 1984; Sutliff & Baldwin, 2001). Learning modes and learning styles that result from differing combinations of these modes are displayed in Figure 1.

David Hunt and his colleagues identified four additional learning styles: northerner, easterner, southerner and westerner (as cited in Kolb & Kolb, 2005). The northerner learning style integrates the RO and AE dialectics and specialises in concrete experience. It combines the characteristics and abilities of the diverging and accommodating styles. The southerner learning style combines elements from the assimilating and converging styles, is flexible with respect to the RO and AE

![Figure 1. Kolb’s learning styles (Adapted from Kolb, 1984).](image-url)
dimensions, and specialises in AC (Kolb, 1984). In mathematics instruction, lectures and exercises are the most common instructional methods used by teachers.

**Lectures and exercises as AC**

Researchers indicate that in mathematics instruction, traditional methods such as lecturing are more well suited to the assimilating learning style (Gardner & Korth, 1998; Jones, Reichard, & Mokhtari, 2003; Kolb & Kolb, 2009; Sharp, Harb, & Terry, 1997). Assimilators are usually rational and they are more interested in abstract concepts rather than in people. They prefer to work individually and avoid practical activities (Bhatti & Bart, 2013; Kolb & Kolb, 2009). Some researchers have argued further that lecturing directly serves the AC learning mode, which is used by both assimilators and convergers (Healey, Kneale, & Bradbeer, 2005; Orhun, 2007; Sutliff & Baldwin, 2001; Svinicki & Dixon, 1987). Similar to assimilators, convergers rely on AC; however, rather than using RO, they prefer the AE learning mode. Therefore, while convergers do not prefer lectures for extended periods of time, they do enjoy solving problems and making decisions by identifying logical solutions to issues or problems (Bhatti & Bart, 2013; Healey et al., 2005; Jones, Reichard, & Mokhtari, 2003; Kolb & Kolb, 2009). In addition to lecturing, exercise-based teaching is a prominent teaching method that is used in mathematics classrooms; it constitutes a crucial component of the problem-solving curriculum (Dana-Picard et al., 2006). In traditional mathematics teaching settings, the teacher transmits theoretical knowledge through lectures and provides application through exercises (Abiodullah & Akbar, 2010; Shandomo & Zelkowski, 2008). Although some exercises may be concrete, especially those given to younger children, this study used exercises that are conducive to AC. The exercises used were either provided in books or written in front of students and were completed by a teacher on a blackboard. This style of exercise administration is used frequently in mathematics education (Dana-Picard et al., 2006). With the primary purpose of this approach being problem solving and practicing, exercise-based techniques used in mathematics classrooms are conducive to the AC and converging learning styles (Cox, 2013; Healey et al., 2005). Related literature has also described the teaching and learning activities that are preferred by accommodators and divergers.

**Manipulatives as a form of concrete experience**

Individuals who are inclined towards the northern learning styles, both accommodating and diverging, prefer learning through concrete experience. Individuals who prefer the accommodating learning style use concrete experience and AE as their dominant learning modes. They use their feelings in decision-making process and they prefer group work (Bhatti & Bart, 2013; Gurpinar, Bati, & Tetik, 2011; Kolb & Kolb, 2005). A common approach used that is geared towards this learning style is ‘hands-on’ learning (Coker, 2000; Davies et al., 1997; Healey et al., 2005; Holley & Jenkins, 1993; Jones et al., 2003; Kolb & Kolb, 2009; Sutliff & Baldwin, 2001). The other northern group, the divergers, who learn best through feeling and reflecting, first attempt to comprehend new information through concrete experience and then later prefer observing and reflecting on their experiences (Kolb, 1984; Kolb & Kolb, 2009). Although divergers do not prefer active learning as much as
accommodators do, it is believed that concrete, hands-on methods will provide reflective thinking opportunities for these learners.

As a form of hands-on learning, manipulatives in mathematics classrooms are considered effective instructional tools. Manipulatives are physical and concrete materials such as cubes, geometry boards, pattern blocks and other everyday objects that help students explore and develop an understanding of mathematical ideas and concepts (Boggan, Harper, & Whitmire, 2010; Bouck & Flanagan, 2010; Clements & McMillen, 1996; Durmuş & Karakırık, 2006).

**Study significance**

This experimental study aims to expand the literature on learning styles by examining the influence of lecture- and manipulative-based instruction on mathematics achievement in students with different learning styles. Previous research shows that the influence of learning styles on academic achievement varies by subject area (Jones et al., 2003). In the disciplines of science and mathematics, either convergers (Biçer, 2010; Davies et al., 1997; Kurbal, 2011) or assimilators were found to be more successful (Özkan et al., 2004). In some cases, both were equally successful compared with accommodators and divergers (Jilardi-Damavandi et al., 2011; Kablan & Kaya, 2013). Convergers and assimilators possess stronger AC skills than do accommodators and divergers. Studies investigating the relationship between learning modes and academic performance across different subjects have reported that AC scores are positively correlated with achievement (Arslan & Babadoğan, 2005; Boyatzis & Mainemelis, 2011; Lynch, Woelffl, Steele, & Hanssen, 1998; Kurbal, 2011; Newland & Woelffl, 1992).

Several factors might explain the greater level of success achieved by southerners in mathematics compared with that of northerners. One of these factors relates to the fact that individuals with mathematical thinking ability typically rely on abstract concepts (Barmeyer, 2004; Kolb & Wolfe, 1981), which is compatible with southerners who excel in AC. Another factor relates to the level of compatibility between mathematics instructors’ teaching styles and students’ learning styles (Jilardi-Damavandi et al., 2011). Accordingly, research shows that when students’ learning styles are compatible with the curriculum design, teaching methods or characteristics of the learning environment, better learning occurs compared with situations in which these factors are not aligned (Claxton & Murrell, 1987; Letele, Alexander, & Swanepoel, 2013; Lovelace, 2005; Onwuegbuzie & Daley, 1998). Previous literature indicates that lectures and exercises are the preferred modes of instruction for AC. When these strategies are used in mathematics instruction, it is inevitable that southerners will be more successful at this subject. However, previous studies on this issue have tended to be descriptive, and experimental studies that test these arguments have not yet been conducted. Further studies are needed to prove that the matching instruction with learning styles yields better learning (Pashler, McDaniel, Rohrer, & Bjork, 2008).

The literature indicates that students who prefer northern learning styles tend to be at a disadvantage when studying mathematics because these students require concrete experiences and manipulatives to fully understand concepts. This study aims to test whether it is possible to close the achievement gap between southerners and northerners by incorporating manipulatives into traditional lecture methods. The findings of this experimental study may provide educators with clues for strategies to eliminate disadvantages among students of mathematics.
The current study explores the influence of manipulatives on mathematics learning outcomes for southerners and northerners. Previous research on learning styles has shown that students with different learning styles show varying levels of performance when certain methods are implemented (Davies et al., 1997; Kvan & Jia, 2005; Tulbure, 2011). Researchers emphasise that in classrooms where multiple teaching approaches are used, there will always be students whose needs are not met when using any given approach (Hayes & Allinson, 1996; Rush & Moore, 1991). Consequently, while matching teaching styles to learning styles in classrooms is ideal for some learning situations, this strategy cannot be generalised to every learning setting (Doyle & Rutherford, 1984; Gilakjani, 2012; Moallem, 2007). Moreover, Boyatzis and Mainemelis (2011) state that active learning strategies in traditional classrooms may not benefit learners who do not prefer or are not accustomed to these activities. Although the positive impacts of manipulatives on mathematics learning have been emphasised in previous studies (Clements, 1999; Olkun, 2003; Sowell, 1989; Suydam & Higgins, 1977), the question of whether students with different learning styles benefit from manipulatives equally has not yet been addressed. This study also contributes to the field by investigating how varying the length of time spent on manipulative learning tools may influence mathematics achievement levels across students of different learning styles. To improve mathematics learning outcomes, the use of concrete experiences alongside abstract learning methods is recommended. However, introducing more concrete experiences into learning environments results in less time for AC. As many mathematics educators have previously proposed, AC is a key component of mathematics education, and concrete experiences are tools for achieving AC (Barmeyer, 2004; Kolb & Wolfe, 1981).

**Purpose of the study**

The primary purpose of this study is to investigate the impact of manipulative use in conjunction with traditional lecturing and exercise methods on mathematics achievement in students with different learning styles. This study not only tests the effect of manipulatives (concrete experiences) on mathematics achievement for students with different learning styles but also examines how varying the length of time spent on concrete experiences influences achievement. To address these issues, three learning environments were created that include varying proportions of traditional teaching approaches and manipulative strategies.

For the current study, the traditional teaching approach and manipulative approach were not treated as mutually exclusive of one another; instead, they were combined in some of the learning environments. In one of the learning environments, the teacher only used lecture- and exercise-based teaching activities, which are more conducive to AC. This approach, also known as the traditional teaching approach, is commonly used in mathematics classrooms. Despite the emphasis on manipulative-based instruction in recent education reform, teachers continue to prefer traditional methods such as lectures in mathematics teaching settings (Levenson, Tsamir, & Tirosh, 2010). Gilakjani (2012) states that teachers not only are used to this approach but also tend to believe that their students will learn more successfully when traditional methods are used.

In another learning environment, the teacher divided his teaching time equally between lectures/exercises and manipulatives. Thus, the effect of manipulative use...
alongside the traditional approach on mathematics achievement in students with different learning styles was assessed.

To test how varying the length of time spent on concrete experiences influences achievement, a third learning environment with less time dedicated to manipulative use than abstract activities (70% lectures/exercises and 30% manipulatives) was also created.

As a whole, this study seeks to answer the following research questions:

1. Do the mathematics achievement levels differ across the different learning styles within the same learning environment?
2. Do the mathematics achievement levels differ among the different learning environments?
3. Is there an interaction effect between the learning environment and the learning styles on students’ mathematics achievement levels?

Investigating the relationships among learning styles, instructional methods and learning environments is critical to the quality of instructional design (Liu & Reed, 1994). The results of this study will provide strategies for accommodating different learning styles in classrooms and suggestions for future instructional design studies in the discipline of mathematics education.

Method

Two experiments were conducted for this study. Experiment 1 employed a single-group design, and experiment 2 used a comparative group design. To control for the ‘teacher effect’ and prevent variations in teaching styles, the same teacher taught in all three learning environments. For this reason, a large sample size could not be used. This led the researcher to conduct two separate experiments. The first experiment involved a single-group design in which each of the four groups received all three treatments sequentially. This design provided a sample size advantage. In the first experiment, the learning differences across the four learning style groups were examined for the different learning environments.

Because the second experiment did not have a sample size advantage, learning styles were investigated as a comparison between the northern and southern learning styles. Despite this limitation, the second experiment allowed for an examination of the impact of learning environments and learning styles, and the interaction effects of these two variables on mathematics achievement, which could not be performed in the first experiment.

Experiment 1

A learning environment is defined in this study as a classroom where different proportions of concrete and abstract teaching strategies are utilised. Three learning environments were designed that employed varying proportions of abstract and concrete activities. Students in experiment 1 were exposed to all three learning environments at different times. The experiment lasted a total of 12 h, during which four hours were consecutively spent in each learning environment. In the first learning environment, 50% of the instruction provided was abstract and 50% was concrete in the form of manipulative use. In the second learning environment, the instruction given
was 70% abstract and 30% concrete. Finally, in the third learning environment, 100% of the instruction provided was abstract in the form of lectures and exercises.

Participants
A total of 101 seventh-grade students in four different classrooms participated in the first experiment. There were 24–26 students in each cohort. With respect to learning styles, 33 (32.7%) students were diverging, 24 (23.8%) were assimilating, 21 (20.8%) were converging and 23 (22.8%) were accommodating. A primary school with standardised test scores above the national average and low dropout and absentee rates was selected for the study. The teacher who voluntarily participated in the study possessed 15 years of teaching experience and was rated highly by the school administration.

Design and treatment
The independent variables of the first experiment were the four different learning styles (diverging, assimilating, converging and accommodating), and the dependent variable was the mathematics achievement post-test for each learning environment. Differences in achievement levels according to the learning styles were examined across the three learning environments.

Figure 2 shows the design of the first experiment. Students in each learning environment were given a pre-test before the lesson to measure their achievement levels. No significant differences in the pre-test scores were found across the different learning styles (Pretest 1, $F = 1.04, p > .05$; Pretest 2, $F = 1.69, p > .05$; Pretest 3, $F = .77, p > .05$). Because the students did not have any prior knowledge on the topic, no differences in the pre-test scores were found between students with different learning styles. After the lesson was completed in each learning environment, the students were given the post-test. The post-test scores were compared across the student groups according to Kolb’s four learning styles.

As shown in Figure 2, the first learning environment divided 160 min of instruction (four lessons) equally between abstract and concrete activities and was called the ‘50% Abstract – 50% Concrete’ environment. As shown in Table 1, in the first lesson provided in learning environment 1, the teacher gave a lecture on polygons during the first 10 min, and students engaged in concrete activities over the

![Figure 2. Repeated measures design.](image-url)
remaining 30 min. These activities required the students to use an isometric geoboard to examine the relationships among polygons, diagonalism and triangles. In lesson 2, students solved exercise questions, which can be described as abstract instruction. For this activity, the teacher wrote the questions on a blackboard and allowed students to solve them on their own. The instructor then lectured the students on the solutions and wrote the answers on the board. In the second half of this lesson, students learned about concave and convex polygons using geometry boards and rubber bands as manipulatives.

As shown in Table 1, the second learning environment involved less time dedicated to manipulatives compared with lecture- and exercise-based instruction. In this environment, 70% of the instructional time was spent on abstract teaching, and 30% of the time was spent on concrete teaching. For example, for the first lesson of learning environment 2, the teacher provided a lecture on patterns for the first 15 min, and over the subsequent 25 min, students created patterns using pattern blocks as manipulatives. For the third learning environment, the entire 160 min of instructional time was dedicated to abstract teaching. For example, for the first lesson provided in learning environment 3, the entire 40-min lesson was spent on lectures and exercises on the properties of a circle. Two other mathematics teachers who teach at the seventh-grade level were consulted when the learning activity durations were being allocated.

Fidelity of implementation
A group of specialists, two of whom were university instructors and three of whom were mathematics teachers, developed the lesson plans used according to the descriptions of abstract and concrete learning activities provided in the literature. These abstract and concrete activities were piloted on a smaller group prior to the study, and some adjustments were made. Each lesson was videotaped, and these videos were reviewed by the university instructors to ensure that the activities were administered according to the lesson plan. Based on the evaluations, it was concluded that the lesson plans adhered to theoretical principles and that the time periods allotted to each activity matched the lesson plan guidelines.

Research instrument
Student learning styles were determined using Kolb’s Learning Style Inventory (LSI)-Version 3 (Kolb, 1999). The Turkish adaptation of Version 3 was produced by
Gencel (2006). Permission to use the inventory was received from Kolb and his colleagues and from Gencel. To measure mathematics achievement, three achievement tests were developed for the three learning environments. The test questions were written in a multiple-choice format and were based on the objectives of the mathematics curriculum outlined by the Turkish Ministry of Education. With respect to cognitive processes, students were expected to use understanding, analysing and applying skills as they are described in Bloom’s revised taxonomy.

**Validity and reliability**

After applying the Turkish adaptation of Kolb’s Learning Style Inventory-Version 3, the reliability coefficients were found to be between .71 and .84 (Gencel, 2006). The achievement test was piloted with eighth-grade students enrolled at the same school. Item difficulties, item discriminations and reliability were computed. Accordingly, for each learning objective, items with high discrimination and moderate difficulty values remained in the test. The KR-20 values for the tests were .75, .77 and .72, respectively. The average difficulty levels of the tests were .45, .46 and .50, respectively. Finally, the average discrimination values of the tests were .44, .43 and .40, respectively. These values were within the acceptable intervals.

**Data analysis**

Statistical analysis of this study was conducted using SPSS 18. The differences in the mathematics scores across students of Kolb’s four learning styles were examined using a one-way analysis of variance (ANOVA). Three separate ANOVA calculations were completed for each learning environment.

**Results of experiment 1**

Before testing for significant differences among the groups, the data were tested for normality. The Kolmogorov–Smirnov test results reveal that the data follow a normal distribution ($Z_1 = .990, p > .05$; $Z_2 = 1.085, p > .05$; $Z_3 = 1.048, p > .05$). Table 2 shows the descriptive statistics of the mathematics post-test scores for the three different learning environments and across the four different learning styles.

The one-way ANOVA results demonstrate that (Table 3) for the learning environment that implemented lecture- and exercise-based instruction throughout the lessons, the assimilators and convergers scored significantly higher than did the accommodators and divergers ($F = 5.237, p = .002$). There was no difference between the assimilators’ and convergers’ scores. In the other two learning environments, where 50% ($F = 1.755, p = .161$) and 30% ($F = 1.907, p = .134$) of instructional time was dedicated to manipulative use, the difference in mathematics achievement levels across all of the learning styles disappeared.

**Experiment 2**

In experiment 2, a comparative group design was used to compare the students’ mathematics achievement levels across different learning environments and learning styles and to test whether learning environments and learning styles impose an interaction effect on mathematics achievement. The independent variables were the three
different learning environments (100% Abstract, 70% Abstract-30% Concrete and 50% Abstract-50% Concrete) and two different learning styles (northern and southern), and the dependent variable was mathematics achievement. The learning styles were divided into two groups due to the restriction on the sample size. Accordingly, following the conventions used in the literature, assimilators and convergers were relabelled as southerners, and accommodators and divergers were relabelled as northerners (Kolb & Kolb, 2005).

Participants
In the second experiment, 78 seventh-grade students were randomly assigned to three different learning environments. Learning environment A included 16 (59.3%) northerners and 11 (40.7%) southerners, learning environment B included 15 (57.7%) northerners and 11 (42.3%) southerners, and learning environment C included 15 (56.0%) northerners and 11 (44.0%) southerners. The distribution of learning styles did not differ across the groups. All groups were taught by the same teacher who taught for the first experiment. Of the 101 students who participated in the first experiment, 78 also participated in the second experiment.

Design and treatment
Although the first experiment offered the advantage of a larger sample size, the fact that the three treatments for this experiment were provided in sequence may have affected the study results. The second experiment did not have this limitation because the treatments were carried out simultaneously in different groups, thereby increasing the reliability of the study results.

As shown in Figure 3, the groups were given a mathematics achievement test prior to the treatment. The pre-test scores ($F_{(2,75)} = .041, p > .05$) indicate no statistically significant differences among the groups. A comparison between prep-test

<table>
<thead>
<tr>
<th>Learning environment</th>
<th>Learning style</th>
<th>$N$</th>
<th>$M$</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract–concrete (50–50%)</td>
<td>Diverging</td>
<td>33</td>
<td>11.03</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>Assimilation</td>
<td>24</td>
<td>13.00</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>Converging</td>
<td>21</td>
<td>11.52</td>
<td>3.14</td>
</tr>
<tr>
<td></td>
<td>Accommodating</td>
<td>23</td>
<td>11.13</td>
<td>3.30</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>101</td>
<td>11.62</td>
<td>3.50</td>
</tr>
<tr>
<td>Abstract–concrete (70–30%)</td>
<td>Diverging</td>
<td>33</td>
<td>12.69</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>Assimilation</td>
<td>24</td>
<td>14.54</td>
<td>4.54</td>
</tr>
<tr>
<td></td>
<td>Converging</td>
<td>21</td>
<td>12.81</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td>Accommodating</td>
<td>23</td>
<td>14.00</td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>101</td>
<td>13.45</td>
<td>3.36</td>
</tr>
<tr>
<td>Abstract (100%)</td>
<td>Diverging</td>
<td>33</td>
<td>9.66</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>Assimilation</td>
<td>24</td>
<td>12.96</td>
<td>3.26</td>
</tr>
<tr>
<td></td>
<td>Converging</td>
<td>21</td>
<td>12.19</td>
<td>4.61</td>
</tr>
<tr>
<td></td>
<td>Accommodating</td>
<td>23</td>
<td>9.73</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>101</td>
<td>10.99</td>
<td>3.94</td>
</tr>
</tbody>
</table>

Table 2. Descriptive statistics of mathematics achievement by learning style in different learning environments.
Table 3. One-way ANOVA results of mathematics achievement by learning styles in different learning environments.

<table>
<thead>
<tr>
<th>Instructional environment</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>p</th>
<th>Differences</th>
<th>effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Between</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract–concrete (50–50%)</td>
<td>62.886</td>
<td>3</td>
<td>20.962</td>
<td>1.755</td>
<td>.161</td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td>Within</td>
<td>1158.81</td>
<td>97</td>
<td>11.947</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1221.70</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract–concrete (70–30%)</td>
<td>62.883</td>
<td>3</td>
<td>20.961</td>
<td>1.907</td>
<td>.134</td>
<td></td>
<td>.06</td>
</tr>
<tr>
<td>Within</td>
<td>1066.16</td>
<td>97</td>
<td>10.991</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1129.05</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract (100%)</td>
<td>217.026</td>
<td>3</td>
<td>72.342</td>
<td>5.237</td>
<td>.002</td>
<td>2 &gt; 1, 2 &gt; 4, 3 &gt; 1, 3 &gt; 4</td>
<td>.14</td>
</tr>
<tr>
<td>Within</td>
<td>1339.96</td>
<td>97</td>
<td>13.814</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>100</td>
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</tr>
</tbody>
</table>

*p < .05.
scores for the nationwide tests also revealed no statistically significant differences among the groups \( F_{(2,75)} = 1.067, p > .05 \). The lessons for the second experiment were all taught by the same teacher. The four lessons spanned a total of 160 min. Students received the post-test after the treatment, and the groups were then compared across learning environments and learning styles.

As in the first experiment, three learning environments were designed with varying lengths of instructional time spent on abstract and concrete teaching activities described in the literature. In contrast to the first experiment, the groups that participated in the second experiment were exposed to only one type of learning environment throughout the treatment period. Thus, comparisons were made between learning environments and learning styles. All of the students were taught the same topic: the Circle and Its Properties. As can be observed in Table 4, Group A received abstract instruction only, Group B received 70% abstract and 30% concrete instruction, and Group C received 50% abstract and 50% concrete instruction. The primary difference in the lessons across the groups was the distribution of abstract and concrete activities; all other factors were controlled across the groups. The duration of a single activity was the same for each group. The quality and implementation of the activities did not vary across the groups.

As demonstrated in Table 4, the concrete activities that lasted 50 min in Group B were the same as those administered in Group C. Group C was provided 30 more minutes of manipulative activity than was Group B. The content delivered over 30 min of manipulative use in Group C was taught through abstract instruction in Group B. The content delivered through both abstract and concrete instruction in Groups B and C was taught only through abstract instruction in Group A.

**Fidelity of implementation**

The lesson plans were developed by the same group of specialists who contributed to experiment 1. Abstract and concrete activities were designed based on the literature. The similarities and differences among the three learning environments were determined. Different proportions of the abstract and concrete activities to be administered across the groups were specified in the lesson plans. Accordingly, if the same
activity was used in several learning environments, the specialists ensured that the implementation of that activity was exactly the same for all three learning environments. Conversely, if an activity was to be differentiated across the learning environments, the specialists assessed the theoretical grounds for differentiation without changing the content. Similar to the first experiment, videos were randomly selected and observed by the university instructors for adherence to the lesson plans and timing guidelines.

**Research instrument**

The student learning styles determined in the first experiment were used in the second experiment. To test the mathematics achievement levels, a multiple choice test that measures understanding, applying and analysing skills was developed.

**Validity and reliability**

The reliability value for the mathematics achievement test was computed as $KR-20 = .76$ after pilot testing. The average difficulty value was .50, and the average discrimination value of the test items was .44.

**Data analysis**

Statistical analysis of this study was conducted using SPSS 18. A two-way ANOVA was used. Learning environments and learning styles were the factors; the interaction effect of these two factors was also examined.

**Results of experiment 2**

Before testing for significant differences among the groups, the data were tested for normality. The Kolmogorov–Smirnov test results showed that the data followed a normal distribution ($Z = .808, p > .05$). Table 5 displays the results of the descriptive statistics on mathematics achievement across the three treatment groups and for the southerner and northerner learning styles.

According to the two-way ANOVA results (Table 6), there were no differences in the mathematics scores among the students in the different treatment groups ($F = .155, p > .05$), and there were no differences in the mathematics scores between the students with different learning styles ($F = 2.256, p > .05$). However, instruc-
tional treatment and learning style did have an interaction effect on the mathematics achievement levels \((F = 4.495, p < .05)\). Figure 4 provides a visual representation of the interaction effect of learning environments and learning styles on mathematics achievement. The analyses of the Bonferroni pairwise comparisons reveal that the southerners \((M = 13.00)\) outperformed the northerners \((M = 8.38)\) in the 100% abstract learning environment \((p = .004)\). No other significant differences were found between students of different learning styles within the same learning environment. Pairwise comparisons also show that the northerners \((M = 12.20)\) in the 70–30% abstract-concrete learning environment outperformed the northerners \((M = 8.38)\) in the 100% abstract learning environment \((p = .009)\). No other significant differences were found among students of the same learning style across the different learning environments.

**Discussion and conclusion**

The findings of the first experiment confirmed those of previous descriptive studies that assimilators and convergers exhibit higher levels of academic performance than do accommodators and divergers (Biçer, 2010; Davies et al., 1997; Jilardi-Damavandi et al., 2011; Kablan & Kaya, 2013; Kurbal, 2011; Özkan et al., 2004). However, the current experimental study found that such learning differences did emerge in environments where only traditional methods were used. In other environments where concrete experiences were used in combination with traditional methods, the differences across learning styles were not statistically significant. This finding indicates that combining learning methods that are conducive to students who prefer northern learning styles with traditional methods would help close the achievement gap between students with different learning styles in mathematics education settings. Similar results were reported for the second experiment. While teachers who use theories, ideas and abstract learning activities in their lessons can meet the needs of

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Northern</th>
<th></th>
<th>Southern</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N)</td>
<td>(M)</td>
<td>SD</td>
<td>(N)</td>
<td>(M)</td>
<td>SD</td>
</tr>
<tr>
<td>Abstract (100%)</td>
<td>16</td>
<td>8.38</td>
<td>4.21</td>
<td>11</td>
<td>13.00</td>
<td>4.47</td>
</tr>
<tr>
<td>Abstract–concrete (70–30%)</td>
<td>15</td>
<td>12.20</td>
<td>4.28</td>
<td>11</td>
<td>10.18</td>
<td>3.81</td>
</tr>
<tr>
<td>Abstract–concrete (50–50%)</td>
<td>14</td>
<td>10.50</td>
<td>2.82</td>
<td>11</td>
<td>12.00</td>
<td>4.07</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>10.31</td>
<td>4.10</td>
<td>33</td>
<td>11.72</td>
<td>4.17</td>
</tr>
</tbody>
</table>

**Table 6. Two-way ANOVA results of mathematics achievement by treatment group and learning style.**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of squares</th>
<th>(df)</th>
<th>Mean square</th>
<th>(F)</th>
<th>(p)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>4.904</td>
<td>2</td>
<td>2.452</td>
<td>.155</td>
<td>.856</td>
<td>.004</td>
</tr>
<tr>
<td>Learning style</td>
<td>35.633</td>
<td>1</td>
<td>35.633</td>
<td>2.256</td>
<td>.137</td>
<td>.030</td>
</tr>
<tr>
<td>Treatment × Learning style</td>
<td>142.006</td>
<td>2</td>
<td>71.003</td>
<td>4.495</td>
<td>.014</td>
<td>.111</td>
</tr>
<tr>
<td>Error</td>
<td>1137.286</td>
<td>72</td>
<td>15.796</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10619.000</td>
<td>78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*\(p < .05\).*
abstract learners, they may lose the attention of those students who require concrete examples and hands-on experimentation to understand concepts (Healey et al., 2005).

A finding from the second experiment also revealed that students with northern learning styles exhibited higher mathematics performance levels in the environment that provided less time for manipulative use (30%) than did their counterparts in the environment where only abstract activities were used. These findings support the observations of previous literature that students with different learning styles exhibit higher performance in certain learning environments but not in others (Davies, et al., 1997; Kvan & Jia, 2005; Tulbure, 2011). Although AC is crucial to mathematics education, abstract learning activities should not be considered the only strategy that can produce successful learning outcomes in mathematics. As demonstrated in this study, concrete experiences must be combined with traditional mathematics methods for students who prefer these experiences.

It was shown that the advantage held by the northerners in the environment in which a reduced amount of manipulatives (30%) was used disappeared when the length of time dedicated to manipulative use increased. This finding may reflect the arguments presented by mathematics educators that abstract thinking is critical for mathematics learning and that concrete experiences can be used as tools for achieving abstract thinking (Barmeyer, 2004; Kolb & Wolfe, 1981). The findings of the current study indicate a potential threshold effect of manipulative use on mathematics achievement. In other words, the effectiveness of manipulative use in mathematics education is comparable to abstract learning to some degree. However, the method may not offer additional benefits to students beyond this threshold because increasing the time spent on manipulative activities detracts from the time reserved for abstract learning activities. While educators support the use of concrete elements in mathematics classrooms, they also warn of their limitations. Educators suggest incorporating more abstraction into mathematics curricula offered in elementary schools (Levenson, Tirosh, & Tsamir, 2006; Wu, 1999).
In the second experiment, while manipulative use increased the mathematics performance of northerners, the performance of southerners neither increased nor decreased compared with the condition in which manipulatives were not used. There are two possible explanations for this outcome. First, while manipulatives were used in the second and third learning environments, a considerable amount of time was spent on AC activities. Southerners may still have taken advantage of the abstract learning activities though the manipulative activities did not appeal to them. Kolb and colleagues (2001) highlight that to meet the needs of different students in a classroom, all learning modes must be considered. When manipulatives and abstract learning activities begin to be used together during mathematics instruction, the needs of different learning styles can be addressed. Second, southerners have the ability to solve problems, understand a broad range of information that they are able to consolidate into logical form (Kolb et al., 2001), and demonstrate superior intellective skills (Bostrom, Olffman, & Sein, 1988). These attributes allow southerners to be more successful in mathematics learning activities. Thus, though the proportion of their preferred learning activities was reduced, they were not affected negatively.

The finding that southerners did not benefit from the manipulative activities can be explained by Kolb’s learning theory. Boyatzis and Mainemelis (2011) emphasised that students who are accustomed to or prefer traditional learning activities may have difficulty adapting to new learning activities. It is important to note that the teachers who participated in this study and Turkish mathematics teachers in general tend to prefer traditional, whole-class methods. This situation may have provided an unfair advantage to the students participating in the study who preferred southerner learning styles. Conversely, Mainemelis, Boyatzis, and Kolb (1999) stated that students with concrete learning styles are more flexible than students with abstract learning styles. Because northerners prefer manipulative activities and are better at adapting to new learning situations, they might have benefited from the concrete experiences to a greater degree than did the southerners.

Recommendations

It can be concluded that using manipulatives in mathematics teaching settings benefits certain learning styles to some degree. First, given the needs of concrete learners, teachers are advised to incorporate manipulatives into their mathematics teaching methods. It is argued that using manipulatives in mathematics classrooms is more beneficial for students who are transitioning from a concrete to abstract understanding of mathematical ideas (White, 2012). Manipulatives can ease the transition from concrete to abstract thinking; however, an excessive use of manipulatives may not help students more than a moderate use.

The findings of this study indicate that the development of flexible learning styles that allow students to adapt to different learning environments can help students increase their achievement levels in mathematics. Consequently, many learning situations in classrooms require using more than one learning style, and students who have not developed adaptive flexibility in learning may face learning difficulties in these situations (Gilakjani, 2012). Adaptive flexibility in learning is defined as ‘the degree to which one changes learning style to respond to different learning situations in their life’ (Kolb et al., 2001, p. 25) or the ability to alternate between concrete experience and AC modes to adapt to concrete and abstract learning situations (Mainemelis, Boyatzis, & Kolb, 2002).
While instructional approaches offered should be conducive to student learning styles, students should also make efforts to adapt their learning styles to new learning situations (Gilakjani, 2012; Hansen, 1997; Loo, 1997; Rush & Moore, 1991). Some researchers have argued that developing flexible learning styles in students that will assist them in different learning activities is more beneficial than providing learning style-based instruction (Hayes & Allinson, 1996; Healey et al., 2005). In fact, the ELT emphasises the importance of using all four learning modes: concrete, reflective, abstract and active (Kolb et al., 2001). The results indicating that manipulative use does not guarantee meaningful learning (Burns & Hamm, 2011; Clements, 1999) might also be dependent on whether students are able to adapt to such learning activities. For the purpose of developing adaptability in learning styles, educators are advised to inform students of the different learning styles, and determine students’ strengths and weaknesses based on these preferences. By specifying the learning activities that are less preferred for each learning style, teachers can help students become more competent in these activities and develop flexibility in their learning styles (Coffield, Moseley, Hall, & Ecclestone, 2004; Isemonger & Sheppard, 2003; Moallem, 2007). Previous research conducted on this issue has shown that students can adapt their learning styles depending on the learning task and subject area with which they are presented (Hayes & Allinson, 1996; Jones et al., 2003). Future research may focus on ways to develop flexible learning skills in students that will help them adapt to different learning situations and, consequently, achieve better learning outcomes.

References


