The experimental teaching in some of topics geometry

Adem Duru
Faculty of Education, Usak University, Turkey. E-mail: adem.duru@usak.edu.tr.
Accepted 12 August, 2010

The aim of this study is to compare the experimental teaching method (ETM) with the teacher centered traditional teaching method based on students’ success. This study is conducted with 54 students, randomly divided into two groups; an experimental group and a control group. Experimental teaching method was used for the experiment group and traditional teaching method was used for control group. The test was applied to both groups in two different times. The first test was applied before and the second test was applied after the teaching. t test was used to compare the two groups and the level of significance was measured as p<0.005. According to the research results, it was found that experimental teaching method was more effective than teacher-centered traditional teaching method in the knowledge and comprehension level.

Key words: Experimental teaching, active learning, geometry, mathematics education, middle school.

INTRODUCTION

Most of the researchers agree that traditional teaching methods are not sufficient in mathematics teaching and other science disciplines (Akinoğlu and Tandoğan, 2006; Kyriacou, 1992; Smith, 1999). In traditional teaching method, most students graduate with memorized information as they are not given chances of problem solving, using information, that is, reforming the knowledge and they are not provided with activities that help them use their thinking skills and that are directed to research skills (Açıkgöz, 2002). Advanced mathematics and other theoretical sciences are often taught purely using the lecture format, which promotes passivity and isolation in students (Rosenthal, 1995). There are big limitations to using traditional teaching approaches in mathematics teaching. According to Rosenthal (1995) many potentially successful students become uninterested in mathematics, and fail to learn it well or to enroll in subsequent courses in the traditional lecture approach to the teaching of mathematics. According to Ernest (1996) the traditional mathematics instruction transmits a view of mathematics as straight forward, logical, absolute and, in most cases, disconnected from reality and independent of both learner and teacher. The role of the learner is also to memorize the facts and rules that are sanctioned by the teacher and to implement them.

Active learning

Mathematics educators and researchers, seeing shortages of traditional lecture approach to the teaching of mathematics, involved in new research directions. Many teaching and learning theories and models have been proposed, developed and implemented in order to enhance teaching and learning of mathematics (Kyriacou, 1992; Sandra, 1995; Rosenthal, 1995; Smith, 1999; Turner and Patrick, 2004).

One of these teaching and learning theories and models is active learning. The term active learning has commonly been applied to a diverse range of learning activities, such as practical work, computer-assisted learning, role play exercises, work experience, individualized work schemes, small group discussions, collaborative problem-solving and extended project work (Kyriacou, 1992). Several active learning strategies have been developed and experimented worldwide in different disciplines, and at different levels of education (Rosenthal, 1995; Tsai, 1999; Telli, Yıldırım, Şensoy, and Yağcı, 2004; Bandiera and Bruno 2006). Studies have
shown that students that have learning experience through active learning do better compared to those students in a traditionally-taught classroom (Felder et al., 1998; Bandiera and Bruno 2006). There has been an increasing emphasis on the use of active learning in mathematics classes (Kyriacou, 1992; Rosenthal, 1995; Smith, 1999; Röj-Lindberg, 2001). When using active learning, students are engaged in more activities than just listening. They are involved in dialog, debate, writing, and problem solving, as well as higher-order thinking, e.g., creativity (Astin, 1985; Bonwell and Eison, 1991). Bonwell states that “in the context of the college classroom, active learning involves students in doing things and thinking about the things they are doing” (Bonwell; 2003). According to Dale’s research, the least effective method at the top of cone, involves learning from information presented through verbal symbols, i.e., listening to spoken word-lectures, while the most effective methods at the bottom of cone involves the student active participation in “hands-on” learning activities.

This view is supported later by other researchers like Stice (1987). According to Stice (1987) students retain 10% of what they read, 26% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of what they say as they do something. Most mathematicians agree that the best way to learn mathematics is by actively doing mathematics; by discussing it with others; and by synthesizing major ideas (Rosenthal, 1995). Waterhouse (1990) has identified two basic characteristics: an emphasis on learning by doing and an emphasis on pupil decision-making. Kyriacou (1992) described it as the use of learning activities where pupils are given a marked degree of ownership and have a control over the learning activities used. Mathematics can be effectively learned only by involving pupils in experimenting, questioning, reflecting, discovering, inventing and discussing. Mathematics should be a kind of learning which requires a minimum of factual knowledge and a great deal of experience in dealing with situations using particular kinds of thinking skills (Ahmed, 1987) Figure 1.

**Experimental activities**

Experimental activities have been used in science education since the middle of 19th century. Experimental teaching method helps to improve students’ hand skills, makes them more productive and increases their active involvement in learning. Students can create a relationship between theory and practice by using experimental teaching method and by applying what they learn into their real life problems through experiments, hence they can make their life more meaningful. Additionally, by using concrete and tangible explanations, students become more involved and absorbed in the lesson (Okan, 1993). Students are active when experimenting and get involved in the experiment excitingly. That is why; activity and high participation is observed

---

**Figure 1.** Dale’s cone of learning (Dale, 1969).
during experiments. Experimental method has a great importance as it ensures student’s active involvement. Observation and learning by doing are the most valid teaching methods of our time (Yıven, 1997). The method using experimental activities gives the opportunity to develop cognitive skills easily and further it gives a lot of opportunities for the students to work in groups or alone. Further, via this method students are also given opportunity to learn by drill and practice (Algan, 1999). Experimental activities encourage affect reasoning, critical thinking, the understanding of science and also help students to develop the ways of producing knowledge (Akdeniz et al., 1998). According to the Council of Higher Education of Turkey, students should participate in the learning activities so that the knowledge can be student’s own product (YÖK, 1997). The main goal to reach for experiment studies is to achieve meaningful learning by putting the theoretical information into practice and by proving it (Nakhleh, 1994). Examining the studies on the importance of experiments, we can see that various types of experiments are carried out for different goals (Domin, 1999; Ergin et al., 2005). Domin (1999) defined four distinct styles of laboratory instruction: expository, inquiry, discovery, and problem-based. Domin differentiated these styles according to three descriptors: outcome, approach, and procedure (Table 1).

The outcome of any laboratory activity is either predetermined or undetermined. Expository, discovery and problem-based activities all have predetermined outcome. For expository lessons both the students and the instructor are aware of the expected outcome. For discovery, and problem-based activities usually it is only the instructor who knows the expected result. A dichotomy also exists for the approach taken toward the activity. Expository and problem-based activities typically follow a deductive approach, in which student apply a general principle toward understanding of a specific phenomenon. Discovery and inquiry lesson are inductive, by observing particularly instances, students derive the general principle. The procedure to be followed for any laboratory activity is either designed by the students or provided to them from an external source (the instructor, a laboratory manual, or a handout). Inquiry and problem-based methods require the students to develop their own procedure. In expository and most discovery activities the procedure is given to the students.

**Geometry teaching**

Geometry is a vital branch of the mathematics curriculum. According to the Principles and Standards for School Mathematics (NCTM, 2000), grade 6–8 students (age 13-15 years) should come to the study of geometry with informal knowledge about points, lines, planes and a variety of two-and three dimensional shapes with geometric relationships. Similarly, the Turkish elementary and middle school mathematics curriculum includes the study of definitions of plane, identifying plane and solid figures, and learning about their properties. It has been observed that students have not been demonstrating strong conceptual knowledge of this subject. Many secondary school students were not prepared for geometry courses (Senk, 1989). Fuys et al., (1988) found that there was too much emphasis placed on formal symbolism and naming in the elementary mathematics curriculum, while relational understanding was underestimated. Junior high and senior high school students often lack experience in reasoning about geometric ideas (Carroll, 1998). Middle school students are capable of developing good reasoning about geometric situations when students have had substantial experience in geometry during elementary school. Many students develop misconceptions and others fail to go beyond simple visualization of geometric figures (Mistretta, 2000).

Although laboratory instruction is used in many disciplines such as physics, chemistry and biology education, it is usually not used in mathematics education. In the mathematic teaching often, after theorems and their proofs have been carefully presented, students are just given exercises. However, as George et al. (1983), and many others have pointed out, mathematics in the making is often an experimental, inductive science. Polya (1954) also very strongly emphasizes the importance of experimental methods, exploration in the discovery or invention of new mathematics and is quoted as one of the most productive mathematicians of all time.

There have been some changes in the curriculum of Primary School Mathematics Education applied in 2005-2006 educational year. It is, in principle, adopted in the new programme that activity-based learning methods used in mathematics education to make students more active in learning. One of these teaching methods is the experimental teaching method. By experimental teaching, we can attain a generalization as can be seen in discovery learning. The method used is actually discovery learning method but sometimes there is a need to use some experiment material to be able to make some discoveries (Altun, 2005). The aim of this study is to determine the effect of student-based experimental method in which students are active and which aims at learning through drill and practice, proving and induction in geometry on students’ success compared to teacher-centered traditional teaching method where students are passive.

**Research questions**

In the present study, was investigated the following...
research questions:

1. In some of topics geometry, is there a significant difference between the successes of students who learn by experimental method in which experimental activities are used and of those who learn by teacher-centered traditional learning method?

2. In some of topics geometry, is there a significant difference between correct answers to questions in knowledge level given by students who learn by teacher-centered traditional learning method and the answers to questions in knowledge level given by students who learn by experimental method in which experimental activities are used?

3. In some of topics geometry, is there a significant difference between correct answers to questions in comprehension level given by students who learn by teacher-centered traditional learning method and the answers to questions in comprehension level given by students who learn by experimental method in which experimental activities are used?

4. In some of topics geometry, is there a significant difference between correct answers to questions in practice level given by students who learn by teacher-centered traditional learning method and the answers to questions in practice level given by students who learn by experimental method in which experimental activities are used?

METHODS

Design of the research

Experimental pre-test and post-test with control group is used as a research method in this study. In this model, there are two groups formed with impartial assignment. One of these groups is used as experimental group and the other as control group. Evaluations are made before and after the experiment in both groups. However, if there is not a significant difference in the pretest results of groups, only post test results are to be used (Karasar, 2000).

Participants

This research was conducted with a randomly selected group of eighth grade students (14–15-year-olds) from two classes in a secondary school in Adiyaman, Turkey. The two classes, a total of 54 students, were taught by the same mathematics teacher. Students were selected randomly taking probability based sampling selection method as basis. The students in the selected sample were divided as those with odd numbers and those with even numbers assigned by their school. Seeing that there is no difference between groups after the first application of the test, experiment and control groups were formed by the use of random sampling method.

Data collection and analysis

In collecting the research data, a test with 10 questions selected from tests prepared in the past years for entrance to secondary school institutions was used. Questions used in the test are made multiple choice questions. Each question used in the test has only one correct answer. The test that covers the topics taught was prepared taking the primary school mathematics teaching curriculum’s content, goals, aims, students’ benefits and teachers. The prepared multiple-choice test was examined by experts and it was determined that it was suitable for the research goals and that it had content reliability. Moreover, as a result of reliability estimates made for the test reliability, Kuder- Richardson (KR-20) reliability co-efficient of the test was found to be 0.74 (Figure 2).

In order to understand if there is a difference between the two groups formed to determine experiment and control group, a test was applied that was prepared for students who did not learn the subject. After seeing that there is no difference between groups, experiment and control groups were formed. Fifteen days later, the subject was taught to the experiment group by using experimental method and to the control group by using traditional lecturing. Four class hours were allocated for teaching pyramid, cone and sphere to both control and experiment group. The lessons for the control group were conducted in the traditional classroom setting and the lessons for the experiment group were conducted in a science laboratory so that students can carry out the experiments more comfortably. The test was re-applied to both control and experiment groups after the topics were fully covered. The correct and wrong answers are given ten and zero points respectively. Then, these are saved in the computer and SPSS 11.0 statistical program was used to measure statistical processes. T-test was used to analyze the data gathered from the test that was applied in order to assess the effect of experimental and lecturing methods on the success level of students in the teaching of pyramid, cone and sphere and to determine the learning and success levels of both groups. In the analyses, the minimum acceptable level of significance was p at a value less than or equal to 0.05.

Procedure

In the experimental method, while measuring the volume of pyramid, pyramids and prism with the same base and height were used and while measuring volume of cone, cone and cylinder

| Table 1. According to Domin (1999) descriptor of the laboratory instruction styles. |
|-----------------------------------|----------------|----------------|----------------|
| **Style** | **Outcome** | **Descriptor** | **Procedure** |
| Expository | Predetermined | Deductive | Given |
| Inquiry | Undetermined | Inductive | Student generated |
| Discovery | Predetermined | Inductive | Given |
| Problem-Based | Predetermined | Deductive | Student generated |
Q 4. Which of the following is the volume of a sphere with radius $r$?

A) $\pi r^3$  B) $4\pi r^3$  C) $\frac{4\pi r^3}{3}$  D) $\frac{3\pi r^3}{4}$

Q 5.

In the figure, the height of the cone and the cylinder is the same and one third of the cylinder is filled with water. When water in cylinder was emptied to the cone, the cone is completely filled with water. If the radius of the cone is $a$ and the radius of the cylinder is $r$, which of the following is true?

A) $a = r$  B) $a = \frac{1}{2} r$  C) $a = \frac{2}{3} r$  D) $a = 3r$

Q 7. What is the radius of sphere whose volume is $500cm^3$. (Take $\pi = 3$)

A) 3  B) 4  C) 5  D) 6

Figure 2. Some of the questions used in the test.

Figure 3. Used materials in the experimental method and activity of calculating the volume of sphere.

with the same base radius and height were used. While calculating the volume of sphere, cylinder whose base radius is equal to its height and the sphere (Ball) whose diameter is equal to cylinder’s basis diameter were utilized (Figure 3).

In experiment method, the pyramid was filled with water and emptied to the prisms so that students can figure out the relationship between the volume of pyramid and prism themselves. By the experiments, the students, on their own, have explored that the rate of the volume of pyramid that has equal height and base to the volume of prism is one thirds. As it is known by the students that the volume of prism is equal to the multiplication of area of base and height, they were able to find by themselves that the volume of the pyramid is $rac{\text{area of base} \times \text{height}}{3}$.

Similarly, students figured out that the rate of the volume of cone to cylinder’s volume is one thirds and found that the volume of cone is $\frac{\pi r^2 h}{3}$ upon having been reminded that the volume of cylinder was $\pi r^2 h$. When measuring the volume of sphere, they were
asked to fill the sphere (ball) with water and empty it into cylinder. Students understood that two thirds of the cylinder was filled with water that was removed from the sphere; hence they found out that the rate of the volume of sphere to the volume cylinder is two thirds.

Students were reminded that \( \pi r^2 h \) and \( h = 2r \) was cylinder’s volume. Then, students calculated that the volume of cylinder as \( \pi r^2 \cdot 2r = 2\pi r^3 \). After observing that the rate of the volume of sphere to the volume of cylinder is two thirds and that the volume of cylinder is \( \pi r^2 \cdot 2r = 2\pi r^3 \) the students were able to come up with \( 2\pi r^3 \cdot \frac{2}{3} = \frac{4\pi r^3}{3} \) is the volume of the sphere.

RESULTS

The first problem of the research is “Is there a significant difference between the success of students who learn by experimental method in which experimental activities are used and of those who learn by teacher-centered traditional learning method in some topics of geometry?”

In order to find an answer to that question, a test made up of 10 multiple-choice questions about volume of pyramid, cone and sphere to be taught was applied so as to see if the students divided into two groups are equal or not. Then, the arithmetic average of groups were calculated taking the answers given by the groups to all the questions into account and although the calculated arithmetical average were so close to each other, a \( t \) test was applied to see if the difference is significant and it was found out that it was not significant. Data related to this is provided in the Table 2.

As a result of the first test applied, of the groups determined as first and second, the average of the first was found to be \( \bar{x}_1 = 23.33 \) and of the second was \( \bar{x}_2 = 23.70 \). As a result of conduct of \( t \) test, as it can be observed in the table as well, it was found to be \( t = -0.117 \). As this value is smaller than critical \( t \) value \( t = 2.00 \) which is in 52 degree of freedom and in 0.05 significance level, there is not a significant statistical difference. In other words, it can be argued that both groups are equal to one another. After observing that both groups are equal, the first group was determined as experiment and the second as control group by the use of random sampling technique.

15 days after the conduct of the test and forming of experiment and control groups, the volume of pyramid, cone and sphere was taught by using experimental method in which experimental activities are used. After teaching the topics, the prepared test was applied to experiment and control groups one more time and the successes of groups were compared. Data regarding this comparison is given in Table 3.

After completion of teaching of the topics and the conduct of the test twice, as can be seen in the Table 3, the arithmetical average of control group was found to be \( \bar{x}_c = 58.88 \) and of the experiment group as \( \bar{x}_e = 45.92 \). A difference of 12.96 was found in favor of experiment group. \( t \) test was applied in order to find if this difference was meaningful and \( t \) value was found to be \( t = 2.85 \). As this value is greater than the critical \( t = 2.66 \) which is in 52 degree of freedom and 0.01 significance level, it is observed that the difference (\( p < 0.01 \)) is statistically significant favoring the experiment group. In other words, it can be argued that compared to traditional method, the experimental method where various activities are used is more effective in 0.01 significance level.

The other problems to the research: In order to find answers to questions ; “In some topics of geometry, is there a significant difference between correct answers to questions in knowledge, comprehension and application level given by students who learn by teacher-centered traditional learning method and the answers to questions in comprehension level given by students who learn by

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>s.d.</th>
<th>t</th>
<th>t-critical</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>First group</td>
<td>27</td>
<td>23.33</td>
<td>8.32</td>
<td>-0.117</td>
<td>2.00</td>
<td>52</td>
<td>0.907</td>
</tr>
<tr>
<td>Second group</td>
<td>27</td>
<td>23.70</td>
<td>14.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. \( t \) Test related to the pre-test results of control and experiment group.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>s.d.</th>
<th>t</th>
<th>t-critical</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>27</td>
<td>58.88</td>
<td>13.68</td>
<td>2.85</td>
<td>2.66</td>
<td>52</td>
<td>0.006</td>
</tr>
<tr>
<td>Control group</td>
<td>27</td>
<td>45.92</td>
<td>19.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. \( t \) Test regarding post-test results of both experiment and control groups.
Table 4. T-test results related to questions in knowledge level given by experiment and control groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>s.d.</th>
<th>t</th>
<th>t-critical</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>27</td>
<td>8.72</td>
<td>2.20</td>
<td>2.49</td>
<td>2.00</td>
<td>52</td>
<td>0.016</td>
</tr>
<tr>
<td>Control group</td>
<td>27</td>
<td>6.48</td>
<td>4.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. T-test results related to questions in comprehension level given by experiment and control groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>s.d.</th>
<th>t</th>
<th>t-critical</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>27</td>
<td>5.93</td>
<td>3.40</td>
<td>4.072</td>
<td>3.46</td>
<td>52</td>
<td>0.000</td>
</tr>
<tr>
<td>Control group</td>
<td>27</td>
<td>2.60</td>
<td>2.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. T-test results related to questions in application level given by experiment and control groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>( \bar{x} )</th>
<th>s.d.</th>
<th>t</th>
<th>t-critical</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>27</td>
<td>4.69</td>
<td>2.01</td>
<td>0.223</td>
<td>2.00</td>
<td>52</td>
<td>0.824</td>
</tr>
<tr>
<td>Control group</td>
<td>27</td>
<td>4.56</td>
<td>2.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

eperimental method in which experimental activities are used?”, the answers given by groups to questions in knowledge, comprehension and application level were compared. Data related to this is provided in Tables 4, 5 and 6.

As it can be seen in the Table 4, the arithmetical average of the answers given to questions in knowledge level by experiment group was found to be \( \bar{x}_e = 8.72 \) and by control group it was found to be \( \bar{x}_c = 6.48 \). Here again, we can observe a difference of 2.24 in favor of experiment group. t test was applied so as to determine if this difference was significant and t value was found as \( t = 2.49 \). As this value is greater than the critical \( t = 2.00 \) value which is in 52 degree of freedom and 0.05 significance level, it is observed that the difference (p< 0.05) is statistically significant in favor of the experiment group.

As it can be seen in the Table 5, the arithmetical average of the answers given to questions in comprehension level by experiment group was found to be \( \bar{x}_e = 5.93 \) and by control group it was found to be \( \bar{x}_c = 2.60 \). We can observe a difference of 3.33 in favor of experiment group. t test was applied so as to determine if this difference was significant and t value was found as \( t = 4.072 \). As this value is greater than the critical \( t = 2.00 \) value which is in 52 degree of freedom and 0.05 significance level, it is observed that the difference (p< 0.001) is statistically significant in favor of the experiment group.

As it can be seen in the Table 6, the arithmetical average of the answers given to questions in application level by experiment group was found to be \( \bar{x}_e = 4.69 \) and by control group it was found to be \( \bar{x}_c = 4.56 \). We can observe a difference of 0.13 in favor of experiment group. t test was applied so as to determine if this difference was significant and t value was found as \( t = 0.223 \). As this value is smaller than the critical \( t = 2.00 \) value which is in 52 degree of freedom and 0.05 significance level, it is observed that the difference (p< 0.05) is not statistically significant in favor of the experiment group.

DISCUSSION

In teaching of abstract concepts in primary education, there is a need for activities that will help students learn theoretical information by trying and proving and for the use of concrete materials in which students are actively involved. Experimental teaching method that has been utilized for years in science education, in which laboratory activities are used and that has been proved to be more effective in comparison with traditional teaching method was used to calculate the volumes of pyramid, cone and sphere. According to the test results, it was seen that
experimental teaching method in which laboratory activities are used was more effective than traditional teaching method.

In general success, it was found out that in knowledge and comprehension level questions in experiment group who were taught by experimental method of teaching were more successful than those were taught by traditional teaching method. This result is parallel with what Confucius articulated thousand of years ago “I hear, I forget; I see, I remember; I do, I understand” and with many researchers’ findings such as Dale (1969), Stice (1987), Nakhleh (1994), Tsai (1999) and Telli et al. (2004). However, a significant difference was not observed between success of students in experiment and control group in application level questions. This may have resulted from the fact that as the experiments in experiment group took a lot of time, the number of questions solved was not high. Generally speaking, it can be stated that despite of some disadvantages, experimental teaching method was more effective compared to traditional teaching method in geometry topics. We can summarize the advantages and disadvantages of experimental teaching method. The first and most important of all, since students find the theories and rules that are discovered by using mathematics knowledge in high level on their own by trial and error process, it makes learning more enjoyable, easier and increases their success. Second, because students produce knowledge by themselves, they become more involved in lessons which create a continuous activity and liveliness. Finally, this method can be utilized in teaching of not only volume of pyramid, cone and sphere but also in teaching of other geometry concepts. As for disadvantages, activities have to be prepared by teacher beforehand. There appears to be some problems in obtaining the materials to be used in activities and it takes more time to carry out experimental activities in comparison with traditional teaching method.

REFERENCES