ABSTRACT

DEVELOPING THE UNDERSTANDING OF GEOMETRY THROUGH A COMPUTER-BASED LEARNING ENVIRONMENT

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The main purpose of the study was to investigate the effects of a dynamic instructional environment (based on use of Geometer's Sketchpad) on 7th grade students' understandings of lines, angles, and polygons and their retention. Besides that, the students' attitudes towards computer instruction and its relation with students' performance on geometry and retention were investigated.

The study was carried out with 63 7th grade students from two classes taught by the same teacher in a state elementary school. One class was assigned as the experimental group (EG), the other as the control group (CG). Students in CG received the instruction on lines, angles, and polygons by the regular traditional method used at the school**.** In the EG, students worked on the computer activities named

as "Sketchsheets", prepared by the researcher, with computers provided at the computer-lab. The usage of GSP with Sketchsheets enabled students to create the shapes first and after they explored and discovered the properties of shapes and make generalisations for the development of conjectures.

Geometry Performance Test (GPT) and Computer Attitude Scale (CAS) were used in this study. The GPT was administered to both groups of students as a pre-test, post-test, and a delayed post-test. CAS was administered only to the EG students as a post-test. Furthermore, interviews were carried out with three students from EG in order to get their feelings about the dynamic instructional environment. Besides that, both of these classroom and computer sessions were observed and recorded with camera.

The results of t-test suggest that GPT mean scores in EG and CG did not significantly differ in pre-test, but EG achieved significantly better than the CG in post and delay-post tests. CAS mean scores and interviews showed that students had positive feelings and decisions towards computer instruction and they preferred computer instruction to traditional instruction. Furthermore, Pearson product-moment correlation coefficient was performed in order to investigate the relationship between GPT scores and CAS scores. From this analysis, a significant correlation was observed between the GPT scores and CAS scores. This means that the students who had positive attitudes towards computer instruction, achieved significantly better at GPT.

The results of this study revealed that Geometer's Sketchpad for learning and teaching geometry in elementary school level is an effective tool.

Keywords: Computer-Based Learning, Dynamic Instructional Environment, Geometry Performance, Attitude Towards Computer.

ÖZ

GEOMETRİK KAVRAMLARIN BİLGİSAYAR DESTEKLİ ÖĞRENİM ORTAMINDA GELİŞTİRİLMESİ

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Bu çalışmanın amacı, dinamik eğitim ortamının (Geometer's Sketchpad kullanımına dayalı) 7. sınıf öğrencilerinin, doğru, açı ve çokgen kavramlarının öğrenime ve kalıcılık etkisini incelemektir. Bunu yanı sıra, öğrencilerin bilgisayara yönelik tutumlarını ve bunun öğrencilerin geometrideki performansları ile kalıcılık arasındaki ilişkiyi de incelenmiştir.

Bu çalışma, bir devlet ilköğretim okulunda, aynı öğretmen tarafından öğretilen iki adet 7. sınıftan 63 öğrenci ile tamamlanmıştır. Bu iki sınıf deney grubu (EG) ve kontrol grubu (CG) olarak belirlenmiştir. Kontrol grubundaki öğrenciler, doğru, açı ve çokgen konularını geleneksel öğretim yöntemi ile sınıf ortamında

öğrenmişlerdir. Deney grubundaki öğrenciler ise aynı konuları, araştırmacı tarafında hazırlanan, "Sketchsheets" adı verilen bilgisayar aktiviteleri ile bilgisayar lâboratuarında çalışmışlardır. GSP ile Sketchsheet' lerin birlikte kullanımı, öğrencileri geometrik şekilleri önce yaratmaya sonrada bu şekilleri keşfedip, özelliklerini tahmin edip, bu tahminlerden genel sonuçlar çıkarmalarını sağlamıştır.

Bu çalışmada Geometri Performans Sınavı (GPT) ve Bilgisayar Tutum Ölçeği (CAS) kullanılmıştır. GPT her iki grup öğrencilerine de öntest, sontest ve kalıcılık testi olarak verilmiştir. CAS ise sadece EG öğrencilerine sontest olarak verilmiştir. Ayrıca, EG' dan seçilen üç öğrenci ile onların dinamik öğretici ortamları hakkındaki duygu ve düşüncelerini almak için yüz yüze görüşmeler yapılmıştır. Bunun yanında her iki sınıf ve bilgisayar dersleri gözlenmiş ve kameraya kaydedilmiştir.

T-test sonuçları, EG ve CG öğrencilerinin GPT puanları ortalamalarında, öntestte belirgin bir fark bulunmadığını fakat EG'un sontesttte ve kalıcılık testinde CG'una göre belirgin bir farkla daha başarılı olduğunu ortaya çıkarmıştır. CAS ve yüz yüze görüşmeler de, öğrencilerin bilgisayar destekli eğitime karşı olumlu duygu ve düşünce içerisinde bulunduklarını ve bilgisayar destekli eğitimi geleneksel eğitime tercih ettiklerini göstermiştir. Ayrıca, Pearson korelasyon katsayısı da GPT puanları ile CAS puanları arasındaki ilişkiyi incelemek için hesaplanmıştır. Bu analizden, GPT puanları ile CAS puanları arasında anlamlı pozitif katsayısı bulunmuştur. Bu sonuç, bilgisayar eğitimine karşı olumlu tutumları olan öğrencilerin GPT' de daha başarılı olduklarını göstermiştir.

Bu çalışmadan elde edilen sonuçlar, dinamik yazılım programı olan Geometer's Sketchpad' in geometri eğitim ve öğretiminde, ilköğretim seviyesinde etkin bir araç olduğunu göstermektedir.

Anahtar Sözcükler: Bilgisayar Destekli Öğrenim, Dinamik Öğretici Ortam, Geometri Performansı, Bilgisayara Karşı Tutum

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LIST OF ABBREVIATIONS

GPT	: Geometry Performance Test
CAS	: Computer Attitude Scale
GSP	: The Geometer's Sketchpad
CG	: Control Group
EG	: Experimental Group
N	: Sample Size
KR-20	: Kuder-Richardson 20 Formula
$\overline{X}$	: Mean
ES	: Effect Size
t	: t-Test Value
p	: Significance Value

CHAPTER I

INTRODUCTION

Geometry is one of the important area of mathematics over the world. Geometry provides experiences that helps students develop understanding of shapes and their properties. It enables students to solve relevant problems and to apply geometric properties to real-world situations. National Council of Supervisors of Mathematics endorsed that geometry was one of the ten proposed basis skill areas (NCSM, 1976). Geometry is indeed a basic skill that should be taught to students of all ability levels (Sherard, 1981).

For many decades educators and mathematicians have discussed the proper balance between the theoretical and practical in the teaching of geometry. Traditional elementary and middle school geometry curricula focus on having students learn list of definitions and properties of figures. Lingquist and Kouba (1989) investigated the results of the Fourth Mathematics of the National Assessment of Education Progress (NAEP) conducted in 1986. They reported that there was minor improvement in the results of secondary school geometry over the previous years. Also, they reported that students had difficulties in application and writing proofs, although they could recognise and identify common geometric figures. Thus, the results showed that secondary school students were at best weak in application of properties of geometric figures, construction of geometric figures, writing proofs and problem solving. The researchers attributed these results directly to poor, inadequate and antiquated instructional strategies used to teach geometry, namely the memorisation of the facts and theorems. Instead of memorising properties and definitions, students should develop personally meaningful geometric concepts and ways of reasoning that enable them to carefully analyse spatial problems and situations (Battista, 2001). Therefore, it is very important that educators and mathematicians use every instructional tool, in particular the use of technology, to improve students' geometric thinking.

Technology is promoted an effective tool to teach and learn geometry. When technology is used appropriately, it can provide a rich environment in which students' geometric understanding and intuition can be developed (NCTM, 1989).

> The use of technology in instruction should further alter both teaching and learning mathematics. Computer software can be used effectively for class demonstrations and independently by students to explore additional examples, perform independent investigations, generate and summarise data as a part of project, or complete assignments. Calculators and computers with appropriate software transform the mathematics classroom into a laboratory much like the environment in many science classes, where students use technology to investigate, conjecture, and verify their findings (NTCM, 1989, p. 128).

Various authors advocate the use of dynamic computer environments to study geometry, as they provide learning through discovery, develops problem–solving skills and supports the teaching geometry (Battista, 2001; Hoffer, 1983). In addition, spatial skills can be improved through the use of a dynamic geometry software (Battista, 2001).

According to the Principles and Standards for School Mathematics (NCTM, 2000), spatial visualisation building and manipulating mental representations of two-and three-dimensional objects and perceiving an object from different perspectives – is an important part of geometric thinking. Researchers who studied in this field of mathematics education emphasised that visualisation is a core part of geometry and indeed in mathematics general (Bishsop, 1989; Eastman, 1973; Hershkowitz, 1989).

According to Eastman (1973) spatial visualisation and general reasoning ability seem the most promising characteristics to consider when planning an instruction in geometry. Geometry can be contemplated as the origin of visualisation in mathematics. Improving spatial ability may be one component to improving students' geometric thinking.

One of the important vehicle of technological chance in geometry classroom is the use of Geometers' Sketchpad (GSP) (Jackiw, 1991). This software allows mathematics to be taught visually to the class as a whole, to small groups, or to individuals by creating dynamic and productive three way interaction between teacher, student, and computer (Hativa, 1984). GSP enables a student to "drag" part of configurations around. It enables students and teachers to investigate and construct an unlimited geometric shapes. The shapes are first created and they can be explored, manipulated and transformed to an ideal concept. Students can not be creative enough in a traditional class (Schoenfeld, 1986). GSP puts geometry exploration tools directly in the hands of students, enabling them to test whether their geometric constructions work in general or whether they have discovered a special case of the original construction. This software also has the capability to link synthetic constructions to analytic equations, and co-ordinate representations. Furthermore, challenging and time consuming provides mathematical problems could be more easier through dynamic software (Lappan and Winter, 1984). As a result, GSP is used for exploration and guided or open-ended discovery—enabling students to test their conjectures and be more engaged in their learning.

When the literature was searched, the studies were investigated the geometric learning of secondary school students' during instruction, on the basis of the Van Hiele model, with GSP as a tool (Battista, 2002; Choi-Koh, 1999). Furthermore, these studies were conducted with small groups (case studies) and investigated how students moved to higher levels of Van Hiele geometric thinking (Battista, 2002; Choi-Koh, 1999). Battista (2002) studied with three children on learning of quadrilaterals (parallelograms), and Choi-Koh (1999) studied with one child on learning of types of triangles (scalene, equilateral and isosceles). Shaw and Durden (1998) used case study method to investigate a celebral palsy student' geometry learning, especially how she understands angles under the usage of GSP. Only Dixon (1997) used GSP in the computer lab environment in the learning of the concepts of reflection and rotation. When we looked at these case studies, the topics of polygons, especially the types of quadrilaterals and triangles, were investigated (Battista, 2002; Choi-Koh, 1999).

Besides the importance of the students' geometry performance under dynamic computer instruction, the students' attitude towards computer instruction and the relationship between their attitude and their geometry performance are very important. The attitudes of participants in any activity are important to its success. Personal attitudes about using computers in a learning environment can be critical to the success of a computer-based project (Clements, 1981). Knapper (1978) has observed that students resistant to computer implemented instruction at the beginning of a course learn less than they would with traditional instructional method. A review of the literature revealed that there no studies which investigated the relationship between students attitude towards computer environment and geometry performance in which GSP is used.

Having established these facts, it seems logical to examine the effect of GSP on students' understanding of and performance in lines, angles and polygons. Furthermore, this study, adding to other relevant studies, investigated the effect of on students' retention and the students' attitudes towards computer instruction and its relations with students' performance on geometry and retention were investigated. The following research questions were addressed in this study:

- Is there a significant mean difference in the performance scores of the EG and CG students on geometry prior to the treatment on geometry?

- Is there a significant mean difference in the performance scores of the EG and CG students on geometry upon the completion of the treatment?

- How rich is the concept image of two groups, as expressed in the justifications procedure? What is the status of the prototypical examples?
- What are the students' attitudes towards dynamic instructional environment?
- Is there a significant correlation between the performance scores and attitude scores?
- What are the students' opinions about dynamic instructional environment and GSP?

The theoretical framework of the dynamic instructional environment was based on an interactive drawing environment in which the students can construct and explore the geometric figures by manipulating them. This ability of manipulating a figure and observing the effects on measurements enabled students to discover relationships for the development of conjectures for themselves and to make generalisations.

1.3 Definitions of Terms

Computer Based Learning (CBL): The use of the computer as an aid or as a supplement in the teaching/learning process.

Dynamic Geometry Software: Dynamic geometry software allows the user to create and then manipulate points and lines on screen. Some points and lines may be freely moveable, but others can be created to be in a geometric relationship to these, such as the midpoint of a line, or a perpendicular bisector of another line. Such relationships are maintained consistently when points are moved.

Geometer's Sketchpad: GSP is a software program (Jackiw, 1991) is an ideal environment for making and testing conjectures and may facilitate the spatial structuring process and the reasoning required for translating two-dimensional representations in to their three-dimensional counterparts.

Traditional Instruction: A style of teaching that includes the teacher at the centre of instruction, and where students learn geometry and other mathematical concepts using pencil-and-paper activities.

CHAPTER II

REVIEW OF RELATED LITERATURE

" The best way to learn anything is to discover it for yourself.
Let them learn guessing. Let them learn proving.
Do not give away your whole secret at once – let the students guess
before you tell it – let them find out for themselves as much as is feasible."

George Polya (p,116)

This chapter provides an explanation for the theoretical framework of the study.

2.1 Why is It Important to Teach Geometry?

The traditional geometry which was gathered by Euclid more than 2000 years ago, had started from what can be seen with the space and shapes provide the environment in which the student can get the feeling for a mathematical theory (Freudenthal, 1973). There are two basic aspects of teaching and learning geometry: viewing geometry as the science, as the science of space and viewing it as a logical structure, where geometry is the environment in which the learner can get a feeling for mathematical structure (Freudenthal, 1973). At a more improved stage, this geometry environment acquires a broader sense, without the necessity of a real environment as a basis.

In 1976, National Council of Supervisors of Mathematics endorsed that geometry was one of the ten proposed basis skill areas (NCSM, 1976). They reported the goals of teaching in Geometry that developing pupils' visual awareness and ability through consideration of figures, and providing insight into the properties and interactions of these figures of these figures. Geometry is indeed a basis skill that should be taught to students of all ability levels (Sherard, 1981). The responses to the Priorities in School Mathematics survey (NCTM, 1981) stated a great deal of agreement on the goals of geometry. Those responding believe that geometry is taught primarily to:

- develop logical thinking abilities
- develop spatial intuitions about real world
- impart the knowledge needed to study more mathematics ; and
- teach the reading and interoperations of mathematical arguments.

From these reports it is seen that spatial visualization and general reasoning ability seem the most promising characteristics to consider when planning instruction in geometry (Eastman, 1973) .

2.2 Spatial Thinking

Visualisation refers to the ability to represent, transform, generate, communicate, document, and reflect on visual information (Hershkowitz, 1987). There is no general agreement about the terminology to be used in this field: It may happen that an author uses, for example , the term 'visualisation' and another author uses ' spatial thinking', but they are sharing the same meaning for different terms.

Spatial thinking is essential to scientific thought; it is used to represent and manipulate information in learning and problem solving

(Gardner, 1983). Hadamard (1996) argued that much of the thinking required in higher mathematics is spatial in nature. Numerous mathematicians and educators have suggested that spatial ability and visual imagery play vital roles in mathematical thinking (Lean and Clements, 1987; Wheatley, 1990).

Yakimanskaya (1971) has emphasized the that, "Visualizations are used as a basis for assimilating abstract [geometric] knowledge and individual concepts" (p.145). For instance, understanding the concept of rectangle and its properties require students analyze spatial relationship of the sides of a rectangle – that is, understand 'opposite' sides and distinguish them from 'adjacent' sides. It was discussed that teachers should provide activities for developing students' spatial imagination so assimilation would be 'formalistic' whether the teacher did not develop students' spatial images, but provided verbal information about the attributes of figures instead.

Hershkowitz (1989) pointed out the role of visualization in the development of a student's conceptualization of a geometric idea and related this development to the van Hiele levels. First, a prototypical example is used as a reference to which possible examples are compared visually (Level 1). Second, the prototypical visual example is used to derive the critical attributes of the concept (transition from level 1 to level 2), which are applied in judging other shapes. Finally, the critical attributes of the concept are used to judge whether shapes are examples of the concept (Level 2). Clements and Battista (1990) found similar developmental results among students doing geometry in a computer environment.

The computer visualization becomes a scientific and mathematical tool. Thus, visual education is required for effective and correct interaction with shapes, relationships between them, transformations on shapes, relationships between shapes and entities etc. (Hershkowitz, Parzysz and van Dormolen, 1996).

Computer exposes a dynamic dimension into this research on visualization because the representations of the 2D shapes on the screen can be manipulated and transformed in many ways. The computer puts some constrains that push the students to use geometrical properties of the shapes and not just perceptual information.

2.3. Figural and Conceptual Aspects in Learning

The argument that definitions and some special examples play an important role in concept learning is long-standing in the psychological and educational research literature (Schwarz and Hershkowitz, 1999; Vinner, 1991). Indeed, several different research studies have produced a sizeable body of theoretical analysis and empirical evidence regarding how definitions and special examples play an important role in concept learning (e.g. Furinghetti and Paola, 1999; Matsua, 2000; Shir and Zaslavsky, 2001).

Definitions play a central role as a concept or a category has a rules system that clearly defines the boundaries of the concept or the category as well as its critical attributes – the attributes that each example should have in order to belong to the category (Bruner, Goodnow and Austin, 1956). In the case of mathematics education, the concept is derived from its mathematical definition and hence has relevant (critical) attributes and non-critical attributes (those attributes that only some of the concept examples possess). The verbal definitions itself usually includes a minimal subset of relevant attributes sufficient to define the concept (Hershkowitz, 1990). When a concept name is seen or heard, usually the concept image is evoked not the concept definition. The concept image is the total cognitive structure that is associated with the concept, which includes visual representations, impressions, experiences, and all the mental pictures associated with the concept name. The portion of the concept image activated at a particular time is called as the evoked concept image (Tall and Vinner, 1981; Vinner, 1991; Vinner, 1983). During the mental processes of recalling and manipulating a concept, some special examples, particularly figures in the case of geometry, are brought into play, consciously and unconsciously affecting the meaning and usage. These special examples are often called prototypes. The prototype is a result of our visual-perceptual limitations which affect the identification ability of individuals, and individuals use the prototypical example as a model in their judgements of other instances (Hershkowitz, 1989, 1990; Shwarz and Hershkowitz, 1999).

According to the general reference frame of the theory of ‘figural concepts’ (Fischbein, 1993), geometry (in elementary, Euclidean terms) deals with specific mental objects, ‘figural concepts’, which possess, at the same time both conceptual and figural aspects. These aspects are usually in tension, so that geometrical reasoning is characterized by a dialectic between them.

The prototype phenomenon and prototypical judgements seem to be mostly a product of visual process (Hershkowitz, 1989). The prototype’s irrelevant attributes usually have strong visual characteristics, and therefore they are attained first and then act as distracters.

Shelton (1985) used a computer program in which 2- to- 6- year old children produced sequences of random examples of isosceles or right triangles of different shapes and orientations. After the interaction, most of the children were free from the upright position prototypes and generalized their concept image of triangles to include all triangular shapes and orientation. Because of this, a rich and dynamic learning environment overcome perceptual limitations.

2.4 The Van Hiele Model of Learning

An overview of mathematical research indicates that the van Hiele (1986) model of development of learning geometry is very important in early competency in geometry. The van Hiele theory of learning geometry has had strong influences on the creation of software programs (Hoffer, 1979). In these dynamic computer software the researchers have tried to develop geometric figures that cover a variety of creative and investigative type of problems that help students in all levels of the van Hiele model.

In the fifties, a mathematics teacher Pierre van Hiele was anxious about secondary school students' performance in geometry lessons. He believed that secondary school geometry involves thinking at a relatively high 'level' and students have not had sufficient experiences in thinking geometry at a prerequisite lower 'levels'. He and his wife Dina van Hiele-Geldof decided to study this problem in their Ph.D dissertation. In this dissertation, van Hiele established a model on levels of geometric thinking based on five levels. These levels have been summarized by Hoffer (1983) and Usiskin (1982) as:

Level 1: (Recognition or Visualization): students identify, name, compare and operate on geometric figures.

Level 2: (Analysis): students analyze properties of figures, but they do not explicit figures or properties.

Level 3: (Ordering): students relate figures and their properties, but they do not organize sequence of statement to justify observations.

Level 4: (Deduction): students prove theorems deductively and establishes interrelationships among networks of problems.

Level 5: (Rigor): students understand the importance of precision in demonstration and analyze various deductive systems.

The van Hiele model focuses on the role of instruction in helping students move from one thought level to the next.

There have been numerous studies (Burger and Shaughnessy 1986; Hoffer, 1983; Usiskin, 1982) that explained in detail this model of development of geometric thinking. In addition, Hoffer (1981) suggested that students need to master large portions of the lower levels in order to function adequately at the more advanced levels on the van Hiele hierarchy.

2.5 Students' Understanding of Line

The subject of lines is one of the important topic in geometry. Especially parallel lines is necessary as a foundation for the classification of polygons, for an understanding of angle relationship, and in geometric proofs. Prior studies showed that students initial understanding of parallel lines was quite unstable (Happs and Mansfield, 1992). One of the important misconception is that students assess segments as parallel and curves as parallel principally on their being equidistant rather than their being non-intersecting. Ubuz (1999) investigated 10^{th} and 11^{th} grade students' basic geometric errors and misconceptions. According to this study students had misconceptions on the subject of lines. Students perceived nonparallel lines as parallel and used complementary angle property in that case. That is, they generalized a property which belongs to a special case. Students also did not know the meaning of a third line that cuts two parallel lines.

2.6 Students' Understanding of Angles

The concept of angle is central to the development of geometric knowledge (Clements and Battista, 1992; Mitchelmore, 1998; Krainer, 1991). Nevertheless, students often harbor misconceptions and experience difficulty learning relevant concepts and skills in these topics. But there is insufficient number of research on these subjects. Ubuz (1999) found that students had misconceptions on special angles occur when a pair of parallel lines cut by a transversal. Students, by looking at the given figures, assume that somethings are given. Some of the studies investigated the difficulties in applying the notions of angle and parallelism at space (Kopelman, 1996), some of are about the difficulties at angle measures as to their definitions (Matos, 1994). Matos investigated the concept of angle exhibited by some 4^{th} and 5^{th} graders of an elementary school. His findings showed that students did not recognize concave angles (angles on a concave vertex of a configuration) as much as they did with convex angles and convex vertices of configuration with curved sides were recognized as angles, even by fifth graders.

2.7 Students' Understanding of Polygons (triangles, square, rectangle, and parallelogram)

There was limited number of studies on triangles. Currie and Pegg (1998) identified and justified the relationships among seven different types, namely, acute scalene, obtuse scalene, right scalene, acute isosceles, obtuse isosceles, right isosceles, and equilateral, triangles by interviewing. As a result of this study, important features about students' views of relationships between figures and students responses were able to interpreted within the SOLO model which was desired to explore and describe students' understanding in the light of the criticisms to work of Piaget. They concluded from the students' responses, a hierarchical framework has emerged which sheds light on the development of student understandings of triangle relationships.

Another study exposed some misconceptions on triangles (Ubuz, 1999). That was students focused on geometric figures itself rather than its properties. Students applied triangle properties on a figure in spite of it was not a triangle and students did not know the meaning of a triangle and the properties of its exterior and interior angles.

A literature review on geometry indicates that there are insufficient number of studies on students' concept images on polygons, square, rectangle, and parallelogram (Burger and Shaughnessy, 1986; Hershkowitz, 1989; Hershkowitz and Vinner, 1983; Hershkowitz, Vinner and Bruckheimer, 1987; Hoffer, 1983; Prevost, 1985; Tsamir, Tirosh and Stavy,1998; Ubuz, 1999; Wilson, 1983).

Burger and Shaughnessy (1986) conducted clinical interviews with the students from kindergarten to college to provide a characterization of the van Hiele levels in terms of specific student behaviors. For example, they observed the following students' behaviors in response to the tasks: 1) references to visual prototypes to characterize shapes; 2) inclusion of irrelevant attributes when identifying and describing shapes such as orientation of the figure; 3) inability to use properties as necessary for a shape; 4) sorting by single attributes; 5) prohibiting class inclusions among general types of shapes. They also noted that the first three findings were on the level 0 and the rests were on level 1 according to the van Hiele levels.

Hershkowitz and Vinner (1983), and Hershkowitz, Vinner and Bruckheimer (1987) investigated students' (in Grades 5-8) and teachers' concept images of basic geometrical concepts. These researchers found that each concept has one or more prototypical examples that are attained first and so exist in the concept image of most subjects. Similarly, Wilson (1983) investigated the relationships between children's definitions of rectangles and their choice of example by asking the subjects to define the concept, and found that the students' choice of examples was based on more on their own prototypes and less on their own definitions. She also found that students wrote definitions that they did not apply when choosing examples. Furthermore, other studies by Hoffer (1983) and Hershkowitz (1989) illustrated such prototypical judgements. Hoffer (1983) reported that students often could not identify a right angled trapezoid as a trapezoid if it does not look like a prototypical trapezoid. Hershkowitz (1989) found that students do not consider a square as a quadrilateral because it has four equal sides and other quadrilaterals do not.

Kulik, Bangert, and Williams (1983) used quantitative techniques to integrate findings from 51 independent evaluations of computer-based teaching in grades 6 through 12. They reported stronger positive effects of computer-based teaching on student achievement. Also, they reported that students who were taught on computers developed very positive attitudes towards computer

Tsamir, Tirosh and Stavy (1998) investigated students' ways of comparing various characteristics of polygons. They focused on students' tendency to deduce, for both triangles and quadrilaterals, the equality of angles from the equality of sides. Their findings determined that students at various grade levels would argue that the equality of the sides and the equality of the angles in any polygon are linked and these led a substantial number of students to erroneous conclusions.

Ubuz (1999) investigated 10^{th} and 11^{th} grade students understanding of basic geometric concepts and showed that students thought trapezoid as a parallelogram without thinking its properties. Another misconception was on 'regular convex polygons'. Students applied properties of regular polygons to any pentagon.

Prevost (1985) studied on identifying and defining polygons with seventh and eight grade junior high school students. He found that most of the students were not able to identify common figures rectangles, squares and trapezoids. Almost all the students could parrot the definitions they had learned at school. If the figures were not oriented properly or were different from anything they had seen before, their definition was 'looks like'.

2.8 Computer-Based Learning Environments in Geometry

The key feature of the computer is its ability to allow its user to explore, investigate and pose problems, and to offer flexible representations of situations, of which at least is on symbolic, and formal level (Noss, 1987). As Fey (1984) stated, computers provide an ideal medium for doing geometry. Geometry permits interesting recent developments based in the new access to direct manipulation of geometrical drawings, which allows to view conceptualization in geometry as the study of the stationary properties of these 'drawings' while dragging their components around the screen: the statement of a geometrical property now becomes the description of a geometrical phenomenon accessible to observation in these new fields of experimentation (Boero,1992; Laborde, 1992).

Computer–based learning instruction has been shown to have some benefits for teaching geometry (Knerr, 1982), and computer-based instruction was found to be slightly better for teaching verbal concepts related to geometry, whereas the traditional approach was better for teaching non-verbal ideas (Kantowski, 1981).

In the computer environment 'continuous variation of geometric figures' (Kakihana and Shimizu, 1994) had a significant effect on students' geometrical performance.

Dortler (1993) supports the view that with computer tools, geometric figures, constructions and system of relationships themselves can become the objects of the activity.

The contribution of the modern dynamic geometry software is two-fold: First, it provides an environment in which students can experiment freely. They can easily check their intuitions and conjectures in the process of looking for patterns, general properties, etc. Second, dynamic geometry software provides non-traditional ways for students to learn and understand mathematical concepts and methods (Marrades and Gutierrez, 2000).

A number of studies have emphasized the role of dynamic geometry software in teaching and learning geometrical shapes. First, Logo, at the beginning of the 70’s ,assemble a specific bridge between geometry and graphical phenomena. Logo is completely defined by a set of primitive actions and objects (i.e., numbers & lists), and a syntax that defines allowable combinations of actions and manipulations (Balacheff and Kaput, 1996). Since its development, Logo has been increasingly used as an environment for students to explore geometry. Logo provided a powerful and flexible environment for students’ representations and exploration of geometric ideas. Positive impacts of Logo programming have been documented for geometric learning among children in grades 1-5 by Clements (1987). Other affirmative consequences were obtained by Olive, Lankenau and Scally (1986) regarding classification of figures and estimating angle and segment sizes, among other topics.

Another research indicated that Logo can be used as a mean to design rich geometrical environments in which students can act and then with appropriate invention come to understand a range of ideas and processes concerning geometrical concepts in a personally meaningful way (Hoyles and Sutherland, 1989; Noss, 1987).

The focus of constructing programs, such as Geometric Supposer software, is to facilitate students making and testing conjectures. The Geometric Supposer is one of the widely used software program at the secondary schools and has a big impact on those classrooms and laboratories where it is used as it was intended, altering the typical geometry course to a very little exercise in conjecturing and reasoning. The Geometric Supposer (Schwartz and Yerushalmy, 1984) made a crucial step by offering the possibility of obtaining modifications of the current Euclidean construction without the necessity to restate completely its specifications.

However, the achievement of the links between geometry and its experimental field, drawings of geometrical shapes have been reached by Cabri-géomètre (Laborde, 1993) replaces the Supposer repeat feature, and then the Geometer's Sketchpad was developed by Jackiw (1991). These dynamic geometry environments are entirely defined by a set of primitive objects (point, line, segment, etc.) and of elementary actions (draw parallel line, etc). The drawings produced at the surface of the screen can be manipulated by 'dragging' and 'grabbing' around any point having sufficient degrees of freedom (Laborde, 1993).

Several articles and books have published on the subject of computer based learning and dynamic geometry software to develop students' geometry understandings.

McCoy (1991) studied the geometry achievement of a class that was used the Geometric Supposer regularly during one academic year and compared it with the class which was implemented by the traditional teaching of geometry. The results of the study concluded that students in the treatment group performed significantly higher on the post-test results.

Kakihana, Shimizu and Nohda (1996) from Japan, conducted a research to investigate how students' strategies shift from conjecture to proof when they utilize measurement in the geometric computer environment. Either first or second grade women's junior college students who had not studied geometry used five pairs of activities. They solved each proof problem for 20-30 minutes after learning how to use Cabri-Geometry for one hour. One computer was used by each pair. A problem on worksheet was given to students and they constructed figures by themselves on a screen. Videotapes, observation reports and written worksheets were analyzed. As a result of this study, they said that, from conjecture to explanation to proof, at the pair situation, the use of information previously obtained and confirmation by measurement and movement of figures in computer environment seemed to help students provide a logical explanation and sometimes a logical proof. In addition to this, they stated the view of explanation in general sense and that of mathematical proof that students have will play crucial role in computer environment.

Chazan (1988) reported that high school students have difficulties in understanding the topic of similarity. After this conclusion, the unit was designed for the use with the Geometric Supposer. Students were observed as they learned similarity with the unit and were given pretest and posttest on fractions, ratio, and proportion, and similarity. A significant result on the posttest was found in the favor of the experimental group. Chazan also reported that the lab environment allows researchers as well as teachers to examine directly thought process in the classroom.

Yusuf (1991) organized a pretest-posttest quasi-experimental design of study in order to determine the effects of Logo Based Instruction compared to traditional instruction. The experimental and control groups was made up of sixty-seven sixth and seventh grade students. Experimental group students were taught the concepts of points, rays, lines, and segments with the basic turtle commands of Apple Logo II. The students in control group were taught the same concepts by teacher using lecture and paper-pencil activities. Analysis of this study showed that the experimental group students scored significantly higher on the posttest than the control group. Moreover, the results showed significant differences in students' positive attitudes toward math, geometry and Logo Based Instruction.

Jones (1998) investigated how using the dynamic geometry package Cabri-Géomètre mediates the learning of certain geometrical concepts, specifically the geometrical properties of the 'family' of quadrilaterals. The data collected from the five pairs of 12 years old students working through a sequence of specially designed tasks requiring the construction of various quadrilaterals using Cabri-Géomètre in their regular classroom over a nine period . She reported the consequences of the study as: a) successful constructions with the software package influences the way learners construct new figures, b) students found the need to invent term, c) how earlier experience of successfully constructing figures can tend to structure later constructions.

Another study was done by Healy (2000) investigated identifying and explaining geometrical relationships using software, Cabri-Géomètre. The study was done with two students and used activity-set. Students wrote their findings, conclusions and proofs on their sheets. The researcher concluded that interaction with a dynamic system like Cabri-Géomètre helps students in defining and identifying geometrical properties and the dependencies between them.

Furinghetti and Paola (2002) studied students' behavior in constructing and classifying quadrilaterals within a dynamic geometry environment, Cabri-Géomètre. Their findings showed that there are kinds of thinking and that are developed as a result of the interaction with the Cabri-Géomètre and suggested considerations on the problem of providing students with a meaningful and active approach to theoretical thinking.

Choi-Koh (1999) investigated a secondary school student's development of geometric thought during instruction using the P.M van Hiele model and dynamic computer software, the Geometer's Sketchpad. The researcher used clinical interview procedure to examine how changes in the student's learning occurred and the relationship of that learning to the van Hiele levels of geometric thought for the geometric topics of right triangles, isosceles triangles, and equilateral triangles. The findings were that computer program was most crucial and effective. It allowed student to focus intensively on specific components and details of complex problems. Also, student was able to easily develop symbols and signal characters not only by observing, discussing, interpreting and conjecturing visual and numerical data.

Shaw and Durden (1998) used case study method to investigate a celebral palsy student' geometry learning, especially how she understands angles under the usage of GSP. They concluded that GSP was beneficial for her because she could make her drawings legible and she could measure angles without relying on her own visual perception

Another study with Geometer's Sketchpad, was done by Dixon (1997) in order to explore the effects of a dynamic instructional environment (based on the use of Geometer's Sketchpad, in a computer lab) and visualization on eight-grade students' (N=241) construction of the concepts of reflection and rotation. The results showed that the students who received the dynamic treatment performed significantly better than who did not received the treatment.

Finally, Battista (2002) investigated how appropriate use of dynamic software can enhance students' geometric reasoning with three student in his study. He concluded that using interactive geometry software, such Geometer's Sketchpad, can foster the development of students' understanding and reasoning about two-dimensional shapes.

2.9 Attitude Towards Computer

As in all sectors of education, developments over the last decade have necessitated a massive increase in post-compulsory students' use of computers. The most important outcome measure of students' computer use is their attitude toward using the technology. Consideration of user attitude is an complementary part of educational computer use.

Lindbeck and Dambrot (1986) developed an instrument to measure attitude toward mathematics and computers which could be implemented in classroom. The findings of their study showed that low mathematics ability is related to math and computer anxiety and negative attitudes.

Gressrad and Loyd (1987) investigated the effects of math anxiety and sex on three computer attitudes which have been identified as related to achievement in computer literacy (Jones, 1983): computer anxiety, computer confidence, and computer liking. They measured them with the Computer Attitude Scale (Loyd and Gressard, 1984), which measures attitudes toward learning and using computers. The results, firstly indicated that three computer attitudes (computer anxiety, computer confidence, and computer liking) were found to be significantly affected by the computer experience. The correlation between computer experience and computer attitudes were moderate and positive suggesting more computer experience corresponding to more positive attitudes. Secondly, the correlation between math anxiety and computer attitudes were moderate and positive, suggesting less math anxiety corresponding to more positive computer attitudes. Finally, the correlation between sex and computer attitudes were found to be generally low, and not statistically significant.

Munger and Loyd (1989) examined the relationship of the sixty high school students' mathematics performance and their attitudes toward computers (computer anxiety, computer confidence, and computer liking) and calculators. The results of the analysis suggested that a significant relationship exists between mathematics performance and attitudes toward technology. Only the computer confidence among three attitudes, contributed significantly to prediction of mathematics performance. Similarly, Troutman (1991) stated that students who feel secure in their own personal use of computers also feel positive toward the use of computers in the schools.

Finally, Levine and Donita-Schmidt (1998) presented a computer attitudes questionnaire which they piloted on school children, from which five main scales were identified. These were; computer self-confidence, attitudes towards computers as an educational tool, stereotypical attitudes, perception of computers as a tool for enjoyment, and importance of computers. First of all, computer self-confidence largely reflected the concept of computer anxiety. Rest of all loaded on to a latent attitude dimension and confidence was reciprocally related to this. Generally, attitudes were significantly associated with commitment to learning about computers.

Attitudes are therefore likely to be important in computer based instruction performance as they make students more willing to use computers.

CHAPTER III

RESEARCH DESIGN AND METHOD

This chapter presents the design and method of the study. The subjects and the instruments together with the scoring criteria are described first. The procedure of the study follows. Then, the treatments for the experimental and the control groups are explained in detail.

3.1 Sample

The participants in this study were 63 7th grade students (32 girls and 31 boys) in a state elementary school in Karabük. There were two 7th grade classes in the school. The same teacher was teaching to both groups. One group constituted the experimental group (EG) and the other the control group (CG). The groups were selected by randomly. EG consisted of 31 and CG consisted of 32 students. Students' ages in both group ranged from 12 to 14. The 31 EG students were composed of 15 girls and 16 boys, whereas the 32 CG students were composed of 17 girls and 15 boys.

3.2 Instruments

3.2.1 Geometry Performance Test (GPT)

The geometry performance test was prepared to investigate 7th grade students' performance on geometry (See Apppendix A). GPT includes twenty two tasks, some of which having some sub-tasks. In the GPT, tasks 12, 15,19, 20, 21 and 22 were taken from the Van Hiele Geometry Test developed for Cognitive Development and Achievement in Secondary School Geometry Project (Usiskin, 1982) and the rests were prepared by the researcher. The test was based on geometry topics given in the 7th grade: Lines and Planes; Angles and Types of Angles, and Polygons (Triangles and Types of Triangles, Parallelogram, Rhombus, Square, Rectangular, and Trapezoid).

Each task in GPT was analyzed by giving 1 for each correct answer and 0 for each incorrect answer. In addition, each explanation given under each tasks was also taken as a different task, and therefore scored as one or zero.

The test including 81 tasks altogether was administered to the subjects as a pre-test and a post-test, and a delayed post-test, allowing 50 minutes. Post-GPT results yielded a Split-Half reliability coefficient of internal consistency of 0.74.

3.2.2 Attitude Scale Towards Computer Instruction (CAS)

A Likert type attitude scale towards computer instruction (CAS) developed by Brown (1966) was used to investigate students' attitude towards computer instruction. As some of the statements of this scale were not suitable for the 7th grade student, 17 of these 43 were selected to be used in this study (See Appendix B). For example, ' I am not in favor of computer instruction because it is just another step toward de-personalized instruction" was not used in the study. In this statement, the meaning of "de-personalized" could not be understood by students. There are 7 negative and 10 positive statements in the scale, with five possible alternatives: Strongly

Disagree, disagree, uncertain, agree and strongly agree. Each statement was graded as 4, 3, 2, 1 and 0 for negative statements, and 0, 1, 2, 3 and 4 for positive statements. Furthermore, four open-ended questions and one multiple choice question were posed to the students to get their judgements and feelings about computer based instruction and their feelings on how much time they can spent on the computer, respectively. CAS was administered only to the experimental group as a post-test, allowing 20 minutes. In this study CAS results yielded a Kuder-Richardson (KR-20) reliability coefficient of internal consistency of 0.93.

3.3 Procedure

The aim of this study was to investigate the effects of a dynamic instructional environment (based on use of The GSP) on seventh grade students' performance on lines, angles, and polygons. This study is an experimental study, in which two different learning environments, traditional and dynamic instructional environment (based on use of GSP) were compared. GSP is a dynamic and interactive computer program that enables students to investigate and explore geometric concepts and manipulate geometric structures. The treatment in the dynamic instructional environment included exploring and manipulating geometric concepts (line, angle, and polygon) based on productive three-way interaction between teacher, students, and computer through subsequent activities, named as Sketchsheets, (See Appendix C) using GSP. The Sketchsheets were designed to permit student inquiry, while guiding, prompting, and helping them to identify relationships and make conjectures. The traditional instructional environment was based on a text-book based approach using chapters related to the lines, angles, and polygons from

İlköğretim Matematik 7 (Yıldırım, 2001), the adoptive text-book for the 7th grade students in the study. The experiment was carried out in both groups at the same time in the second term of the 2001-2002 academic year, lasting five weeks. In the CG, the class teacher taught the geometric topics of lines, angles, and polygons. In the EG, students worked on the GSP activities named as "Sketchsheets", prepared by the researcher, at computers provided at the computer-lab. The introduction to the topics were done in the classroom by the class teacher and the works on these Sketchsheets applied in the computer–lab by the help of the researcher as the class teacher was not experienced in using computer and also GSP, as she mentioned herself. Not causing this to be problem, the researcher helped the students in computer lab during the whole treatment.

The students in the EG and the teacher were taught to use the Geometer's Sketchpad prior to the treatment. All training was conducted by the researcher and lasted approximately two class hours. During training, the students were required to do hands-on activities to aid constructing points, lines, angles, and polygons on the computer. For the study, some Turkish explanations were added to GSP in order to prevent language problems and to help to use GSP effectively.

Both of these classrooms and computer sessions were observed and recorded with camera.

In this study, two instruments were used. The first one is the Geometry Performance Test (GPT), which was developed by taking into account the findings of previous studies. GPT was piloted on three 8th grade students by using face to face interview, identified by their mathematics teacher as having 'above average ability', 'average ability' and 'below average ability in mathematics in the first semester of 2001-2002 academic year. The purpose of the pilot study was to examine students' difficulties on understanding the questions and identify misconceptions and according to these results, to prepare Sketchsheets for the main study. Especially the students' errors and prototypes were taken into consideration. The details of the piloting are given in Chapter IV. The second instrument is the Attitude Scale Towards Computer Instruction (CAS).

The GPT was administered to both groups of students as a pre-test, post-test, and a delayed post-test. CAS was administered only to the EG students as a post-test.

The pre-GPT was administered to the students prior to the treatment to ensure that two groups were equal in understanding of lines, angles, and polygons at 0.05 level of significance. The post-GPT and CAS were administered upon the completion of the treatment.

Finally, a delay post-GPT was given five months after the termination of the treatment to both groups in order to investigate the effectiveness of dynamic instructional environment and its impact on long-term memory.

At the end of the study, researcher made interviews with three students from the EG. In this interview, some questions were posed to the students in order to get their feelings about dynamic instructional environment. These students were chosen randomly from the group.

The Statistical Package for Science (SPSS) was used to conduct statistical procedures on the data. Furthermore, the t-test was applied to pre-test and post-test results to determine the existence of any significant differences between EG and CG. After scoring each item on each test, frequencies of each item on each tests according to the scoring criteria were computed. Furthermore, descriptive statistics were calculated for each test. To calculate group differences on pre-GPT prior to the treatment, independent samples t-test was conducted. Group differences relative to the post-GPT were determined by using again independent samples t-test. Also, for the correlation among post-GPT, delay-GPT, and CAS, the Pearson correlation coefficients were calculated.

3.4 Treatments for the Experimental and Control Group

The main characteristics of the learning environments to which the experimental and control group students were exposed are presented here.

All students received instruction on topics in their regular mathematics classes by using traditional learning method except geometry. Before the study, one class was randomly assigned to the "experimental group (EG)" and the other was assigned to the "control group (CG)". These two groups were taught by the same teacher in the classrooms. The computer activities in the EG were carried out in the computer lab with the help of the researcher. The study lasted five weeks. There were four mathematics classes in each week, two hours in a day, lasting 40 minutes each. In the state elementary school, mathematics is taught by the primary teachers till the end of the 5^{th} grade.The textbook " İlköğretim Matematik 7" written by Yıldırım, (2001) was used in both groups to assign home works.

The approaches used in the CG and the EG are presented in detail as follows.

3.4.1 Treatment for the Control Group

The method used in this class was traditional method. In general, the teacher explained the concepts by writing them on the board, and then allowed students to write them on their notebooks. While starting the lesson, she always reviewed of the previous lesson by writing the important rules or procedures. Then, the lesson was continued either by asking to the students to do some similar exercises, which were worked in previous lesson, or writing new rule or a new definition. Students in the CG were taught using chapters from their textbook (Yıldırım, 2001). The teacher usually used ruler for drawing lines and protractor for measuring the angles. While she was drawing lines or angles, students also drew them on their notebooks by using the same tools. At some exercises, one student among the volunteer students was called to come to the board and show his/her solution of the exercise. Subsequently, the teacher explained again the solution of the exercise upon the completion of the solution by the student. The teacher assigned home works from the textbook each time when the topic was completed.

3.4.2 Treatment for the Experimental Group

Prior conducting the treatment, to familiarize the students in the EG with the GSP and its proper usage, a couple hours of hands-on instruction and practice were given at the computer lab. Two-hours were adequate for the students in using computers as they have been using computers in the Computer Course since the last two years. At the end of this practice all students were capable of constructing points, lines, angles and polygons on the computer. The lab contained

18 computers so students worked in pairs at the computer. They were located in the U shape**.**

The students in the EG spent much of their time on the computer lab. Approximately three class hours of a week were spent in a computer lab and one class hour in a class.

In this class hour in the classroom, the students and the class teacher discussed together the findings come out in the computer-lab and the class teacher made a brief introduction to a new topic. Following the students worked on the Sketcsheets using GSP at the computer lab. 18 Sketchsheets were developed for this study. The objectives of the sketchsheet activities are presented in Table 3.1 and the majority of the Sketchsheets were of an investigative nature. Investigations guided students toward discovering a specific property or small set of properties. Students developed personally meaningful geometric concepts by exploring, manipulating and transforming the geometric shapes. For example, Sketcsheet 9 guides students to make some specific conjectures for the angles of any type of triangles. They are given instructions to create construction of angles of a triangle. In the following time, students measured and manipulated their constructions to see what relationships they can find that can be generalized for all triangles.

At each computer session daily sketchshеets were distributed to the students. Upon a completion on working on each, students wrote their findings on their Sketchsheets. Then, researcher asked students what their findings and conclusions about that activity and wrote the whole findings on the board. In this way, the students discussed and interpret the findings. With this discussion, a sketchsheet was completed and the following Sketchsheet was distributed to the students. The completed results of the completed sketcsheets also discussed in the following first class session with their teacher. All activities in the Sketchsheets were completed in this procedure.

The comparison of the EG and CG is given in Table 3.2.

Table 3.1: Objectives of each activity in Skectsheets

Sketchsheet	**Objectives**
1.	a. Find the positions of two lines being in a plane with respect to each other by drawing lines
2.	According to the findings of 1/a;
	a. Write the intersection of intersecting lines
	b. Write the intersection of coinciding lines
	c. Write the intersection of parallel lines.
	d. Creating congruent angles
3.	a. Create different adjacent angles
	b. Create congruent adjacent angles
	c. Create non adjacent angles but they must sharing same vertex
	d. Create complementary angles
	e. Create congruent adjacent complementary angles
4.	a. Create supplementary angles
	b. Create congruent adjacent supplementary angles
	c. Create straight points
5.	a. Create vertical angles
	b. Write the invention of measures of vertical angles
	c. Write the position of vertical angles in a plane
6.	a. Create two parallel lines and a transversal
	b. Measure the angles that formed in 5/a
	c. Write the features of angles created by two parallel lines and a transversal
	d. Measure the angles when the lines are not parallel
	e. Write the relation between the angles and parallelism
7.	a. Find the corresponding angles from the given figure
	b. Write the relation between corresponding angles
8.	a. Show the interior angles on the given figure
	b. Show the exterior angles on the given figure
	c. Write the relations between exterior angles and interior angles
9.	a. Create three non-linear points and write the name of that shape
	b. Find the sum of measures of the angles of a triangle
	c. Find the sum of measures of the angles of a triangle while changing the triangle by dragging
10.	a. Create the attitudes of a triangle
	b. Write the number of attitudes of a triangle
	c. Create the medians of a triangle
	d. Create the angular bisector of a triangle
11.	a. Create an exterior angle of a triangle
	b. Find the sum of measures of the exterior angles of triangle
	c. Find the relationship between an interior angle and an exterior angle of a triangle
	d. Find the relationship between the interior angles and the length of sides of a triangle

Table 3.1: Continued

Sketcsheet	Objectives
12.	a. Find the measure of the interior angles of an equilateral triangle
	b. Find the relationship between the interior angles of an equilateral triangle
	c. Find the type of interior angles of an equilateral triangle
	d. Find the relationship between three lengths of sides of an equilateral triangle
	e. Find the measures the interior angles of an equilateral triangle while the lengths of sides are changing by dragging
	f. Write a definition an equilateral triangle
13.	a. Find the measure of the interior angles of an isosceles triangle
	b. Find the relationship between the interior angles of an isosceles triangle
	c. Find the type of interior angles of an isosceles triangle
	d. Find the length of three sides of an isosceles triangle
	e. Find the relationship between three lengths of sides of an isosceles triangle
	f. Find the measures the interior angles of an isosceles triangle while the lengths of sides are changing by dragging
	g. Write a definition an isosceles triangle
14.	a. Find the measure of the interior angles of a right triangle
	b. Find the relationship between the interior angles of a right triangle
	c. Find the type of interior angles of a right triangle
	d. Find the length of three sides of a right triangle
	e. Find the measures the interior angles of a right triangle while the lengths of sides are changing by dragging
	f. Find the number of a right angle in a right triangle
	g. Write the definition a right triangle
15.	a. Show the polygons from the given Sketches
	b. Create different polygons on computer
	c. Create regular polygons on computer
	d. Find the attitudes of regular polygons according to their sides
	e. Find the measure of interior angles of regular polygons
16.	a. Find the attributes of a parallelogram according to its angles
	b. Find the attributes of a parallelogram acoording to its sides
	c. Write the definition of a parallelogram
	d. Find the attributes of a rectangle according to its angles
	e. Find the attributes of a rectangle according to its sides
	f. Write the definition of a rectangle
17.	a. Find the attributes of a rhombus according to its angles
	b. Find the attributes of a rhombus according to its sides
	c. Write the definition of a rhombus
	d. Find the attributes of a square according to its angles
	e. Find the attributes of a square according to its sides
	f. Write the definition of a square

Table 3.1: Continued

Sketcsheet	**Objectives**
18.	a. Write the relationships between a parallelogram and a rectangle
	b. Write the relationships between a parallelogram and a square
	c. Write the relationships between a rectangle and a square
	d. Write the relationships between a rhombus and a square
	e. Create a hierarchical classification between shapes with given cards

Table 3.2: Comparison of the EG and CG

Category	**Experimental Group**		**Control Group**
Environment	Classroom	Computer Lab	Classroom
Problem Solving	Textbook problems	Sketcsheets (investigative activities, open-ended questions*)*	Textbook problems
Technology (tool)	....	Geometer’s Sketchpad	Ruler, protractor
Teacher Role	Teacher is reviewer	Teacher is facilitator, students are responsible for the study	Teacher is presenter
Students Role	Reviewing and discussing	Reading, doing, discussing, reporting Conjecturing, interpreting	Reading, doing
Students Interaction	Students work alone or together	Students work alone or in pairs	Students work alone

CHAPTER IV

PILOT STUDY OF THE GEOMETRY PERFORMANCE TEST

The geometry performance test (GPT), including 22 questions was developed for the study in order to determine the students' understanding of lines, angles and polygons.

Three of those 22 questions are from Lines, nine from Angles and ten from Polygons. All the questions in GPT, except two multi-choice questions, were open-ended questions. Open-ended questions were chosen because the students can freely explain the reason for their answer.

The test was piloted on 3 8^{th} grade students, by using face to face interview, identified by their mathematics teacher as having 'above average ability', 'average ability' and 'below average ability'. The purpose of this pilot study is to examine students' difficulties on understanding the questions and identify misconceptions and according to these results, to prepare Sketchsheets for the main study.

Prior to the interviews, an appropriate time schedule was arranged for the students. Interviews were conducted in three days, one day for each student in November 2001. Even there was no time limit for the interviews, each took approximately an hour. Although the interviews for the study were primarily structured, the interviewer spontaneously reacting to students' descriptions of their solutions imposed some unstructured. During the interview the students initially read each problem aloud. Later they were given times to think about it then promoted, to describe, his/her solution and asked to provide justification to the solution offered. After the students' justification, the interviewer made some general inquires, such as, "explain" or "clarify", and continued to ask more specific questions, if necessary, until a response was elicited or it appear that all knowledge had been elaborated. Further, the students were asked to write their responses, if necessary. This process was repeated for each problem. Interviews were type recorded and transcribed.

Analysis of the responses given to each problem, involved a careful reading of each transcription, while attempting to identify common student responses and misconceptions. Oral justifications were used to allow a more detailed qualitative analysis of students' thinking.

4.1. Results

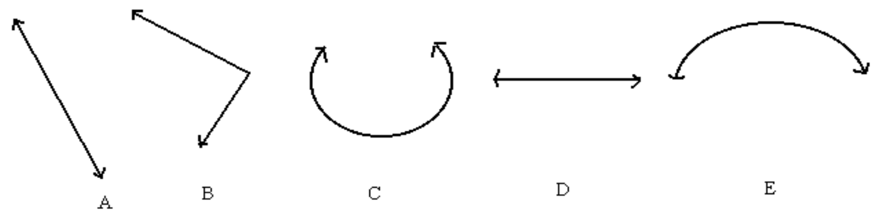
Here the results related to each question on lines, angles, and polygons are presented and interpreted separately. The discussion of the interview results and some excerpts from individual interview transcripts are given.

'Above average ability', 'average ability', and 'below average ability' students were labelled as H, A, and L respectively.

Lines

Question 1

Which of the figure or figures are line(s) ? Explain your reason.



Line is a continuous extent of length, straight without breadth or thickness ; the trace of a moving point.

All the students gave the correct answer that figure A and D are lines. Students defined a line as “ a strap that two of the points goes to infinite”.

Question 2

How many different positions can two lines being in a plane be with respect to each other? Explain your reason.

In a plane two lines can be in three positions with respect to each other.

1- Parallel lines: The intersection of the two lines is empty.
2- Intersecting lines: The intersection of the two lines is a point.
3- Coinciding lines: the two lines are exactly the same lines. (Kaya, 1989).

Student H knew the two forms of the lines and showed these forms by drawing.

H: Two lines can be parallel or they can be in cross way.

I: What is the mean of 'cross' ?

H: Being opposite way

I: What is the meaning of ' being parallel'?

H: Going to same direction

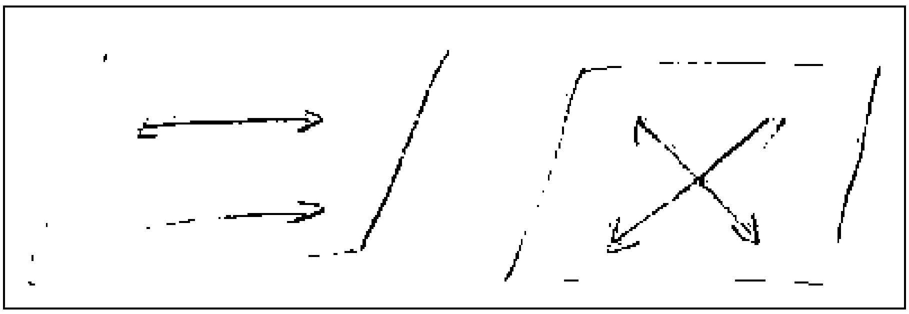
However, student H did not know the position of coinciding. Student A was not aware of the position of parallel and coinciding. She only knew the position of intersection. Student L did not know the positions of the lines and also the meaning of a plane.

A: I think they can be in cross way...like a scissors...

I: What do you mean with 'cross'?

A: They are going to opposite ways..

It is apparent that although the students know or draw the intersecting lines, they have a language problem when defining the forms. Their visual representations are more powerful than defining. In schools and in geometry books, we see that intersecting line figures are more weighted drawn examples than coinciding and parallel lines that are more central to learning than the definition.



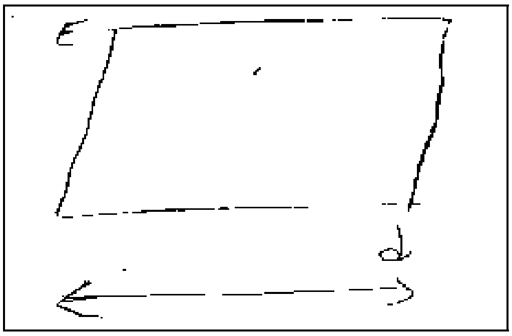
Student H

Question 3

If a plane and a line do not have any shared point, in which condition are they being? Explain your reason.

If a plane and a line do not have any shared point, then they are parallel to each other.

Only student H gave the correct answer by drawing the situation. Student A and L could not give any answer by stating “ I do not know”. We see that the answers of this question is confirm the second question.

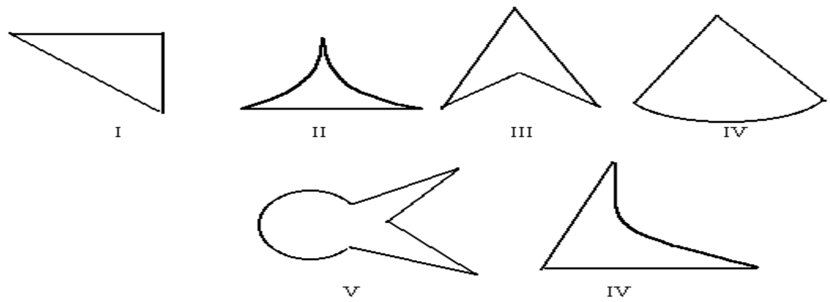


Student H

Angles

Question 4

Show each of the angles with A that are given in the shapes below.



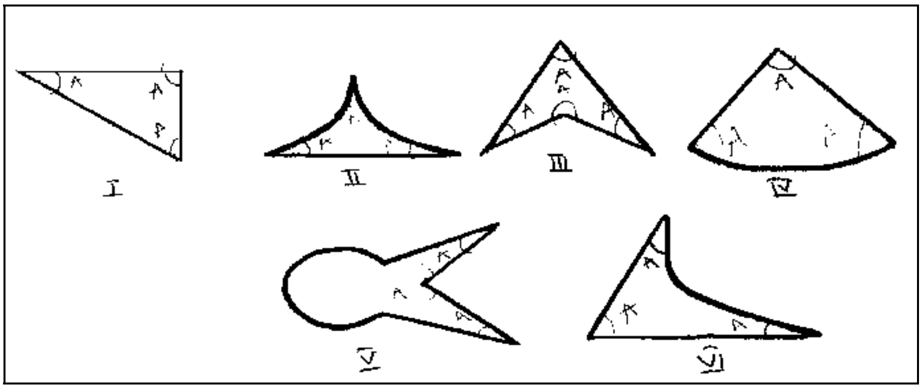
An angle is formed by rotating a ray about its end point (Rockswold, Hornsby, and Lial, 2000). Forming by rays is the critical attribute of angle concept.

All students gave different definitions for an angle but all the definitions had a common point that a angle is a corner.

Student H and L marked the interior corners of each shape as an angle. It seems that these students determined the angles without paying attention to the curves. Although student H defined angle more or less correctly, student L defined angle as only a corner.

I: What is an angle?
H: Every corner in a triangle...
I: How can an angle exist?
H: I am not sure, but they exist when two rays intersect.

L: Angle is a corner
I: Is every corner be angle?
L: Yes



Student H

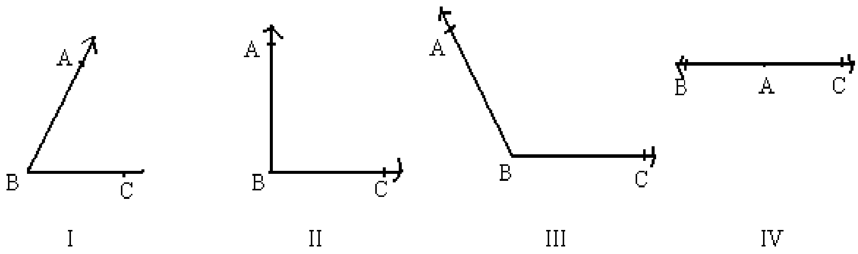
Student A marked interior angles of the shapes correctly by distinguishing the curves. She know the critical attribute of an angle that it is formed by rotating a ray. All students, however, ignored the exterior angles.

R: What is an angle?
A: It exists when two lines intersect, it become a corner.
In the shape II and IV the sides are not lines, they are curves so there can not be angles.

The answers given on this question show that angles are connected with the interior of the shape not the exterior. Because interior angles are more weighted examples.

Question 5

Please define the types of angles.



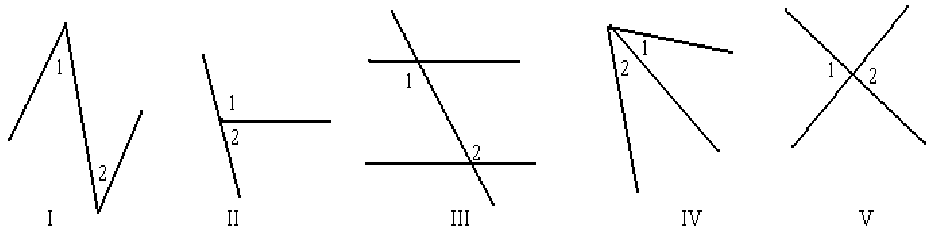
All the students could define the types of angle but they all could not name the straight angle. The following episode is an example.

> *H: I is an acute angle whose measure is less than 90˚, II is a right angle whose measure is 90˚, III is an obtuse angle whose measure is greater than 90˚ and IV's measure is 180˚ .*

Here we can see that students do not have difficulty in naming acute, obtuse and right angle but have difficulty in naming straight angle. The reason might be that acute, obtuse and right angle named as 'dar açı', 'geniş açı' and 'dik açı' in Turkish. *Dar, geniş* and *dik* means "*ensiz, genişliği az veya yetersiz olan", "eni çok olan, kapsamı büyük"*, and "*yatay bir düzleme göre yer çekimi doğrultusunda olan", "eğik olmayan"* respectively in everyday context. These everyday words were borrowed to describe mathematical phenomena of interest. The mathematical contents of acute, obtuse, and right angle do not generate powerful images and feelings of its own. Straight angle, however, named as "doğrusal açı" in Turkish. *Doğrusal* means "*doğru ile ilgili olan, bir doğruyu izleyen".* Students could not use this word in the everyday language so they had difficulty in naming straight angle because straight angle is not use as acute and obtuse angles. In majority 180° is used instead of straight angles. In the end, mathematical language of the students subordinate to the everyday language.

Question 6

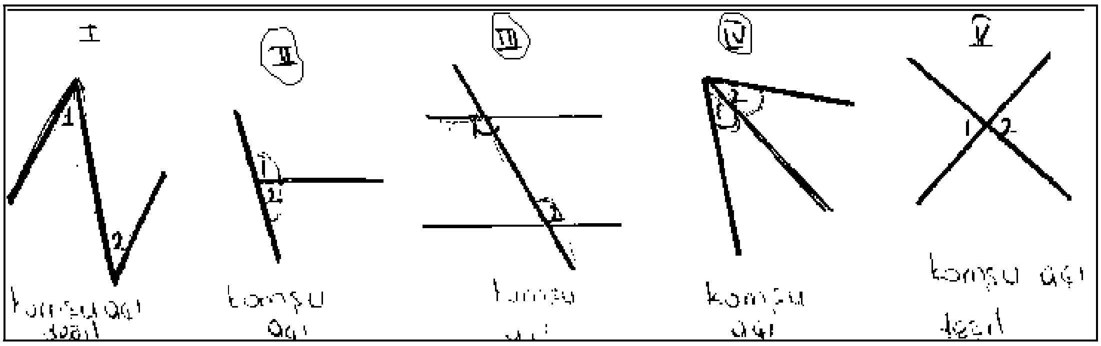
Which of the figure or figures show a pair of adjacent angle (angles 1 and 2). How can you define an adjacent angle to your friend on the phone?



Adjacent angles are two angles which have the same vertex and a common side such that the intersection of their interiors is the empty set (Rockswold, Hornsby, and Lial, 2000). Adjacent angles have two critical attributes. First one is to having same vertex and the one is having a common side.

Student H defined adjacent angle correctly. Although she gave the correct answer that figure II and IV are adjacent angles, she also selected Figure III as an adjacent angles. She did not know the first critical attribute of adjacent angle. This student is not aware of that the common side should start from the same point.

> *H: I can tell adjacent angles...., think two angles,...,These two angles have a common side. I mean that one side of first angle and the second angles side is common. After she must understand...*

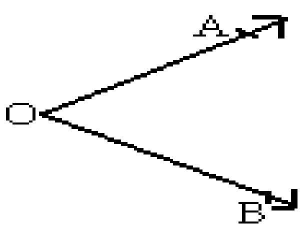


Student H

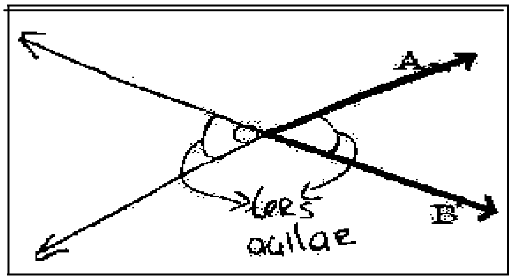
Student A could not give the complete definition of adjacent angle. She stated that “I do not know the definition but.. I think one corner will be the same...”. She selected figure V as well as figure II and IV as adjacent angles. This student is not aware of the second critical attribute that angles should have a common side. Student L could not give the answer.

Question 7

Two angles formed by two intersecting lines and which are not adjacent are called Vertical Angles. According to this definition, draw the vertical angle of angle AOB.



All students could draw the vertical angle of AOB by dragging out the sides.



Student H

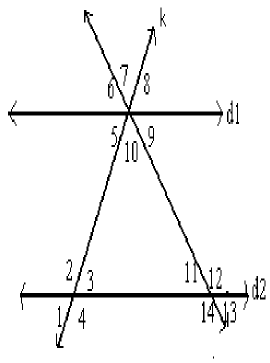
Vertical angle named as *ters açı* in Turkish. *Ters* means "*bir şeyin içe gelen yanı, arkası"* in everday context. When we say *ters açı*, this does not ascribe a new meaning. All students know the everyday context of *ters* so they were successful in drawing.

Question 8

d1 and d2 are parallel lines. According to this diagram;

a) Show a pair of alternating interior angles.

b) Angles 4 and ____ are alternating exterior angles.



Alternating interior angles and exterior angles are congruent when two parallel lines are cut by a transversal. Only student H could show a pair of alternating interior angle correctly by giving example of angles 9 and 11. She, however, determined incorrectly angles 4 and 6 as alternating exterior angles.

Only student H could show a pair of alternating interior angle correctly by giving example of angles 9 and 11. She, however, determined incorrectly angles 4 and 6 as alternating exterior angles. Transversal line which is necessary for the alternating exterior angles could not been visualised completely so they thought that they can use any transversal instead of transversal k in this question. Another result of this question is that this student look for the Z figure with these angles. This shows that the explanations given as Z figure causes a prototype since parallelism is not necessary to be cut by a transversal line.

I: What do you understand from alternating interior and exterior angles?

H: There must be a Z figure , here is one (showed on the figure). I think above corner of Z must be equal to below corner. So angles 9 and 11 are alternating interior angles.

I: Ok, can this Z be any Z?

H: Yes.,...., but I think they must be parallel sides.

Students A and L gave different incorrect answers. Student A showed angles 4 and 2 as an alternating interior angles and angles 4 and 1 as an alternating exterior angles. It is evident that these students focus only to the word ‘exterior’.

I: What do you understand from alternating interior angles?

A: They must be alternate, for example 4 and 2

I: What do you understand from alternating exterior angles?

A: They must be exterior and alternate, 4 and 1 since 1 is exterior.

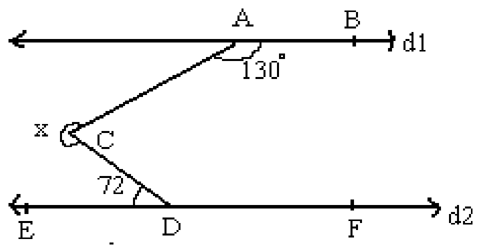
Student L showed angles 5 and 6 as alternating interior angles and angles 4 and 12 as alternating exterior angles. These show that students do not know the concept of alternating interior and exterior angles. It is evident that this student do not pay attention to the word ‘alternating’. The responses of students A and L shows that they did not know the topics of alternating interior and exterior angles. But, when we looked at their responses, the words used for naming the angles were borrowed from the everyday context. This showed that, students gave responses based on these meanings.

Question 9

m(CAB)=130º and

m(CDE)=72º.

Find the measure of angle x?



In this question students can draw a parallel line to d1 and d2 from the point C. Then they can use alternating interior angle property. Student H found the correct solution as it is explained. But, Student A and L could not find the solution. Student A only found the supplementary angles of angle CDE and CAB. Student L connected the points A and D and formed a triangle but could not go further.

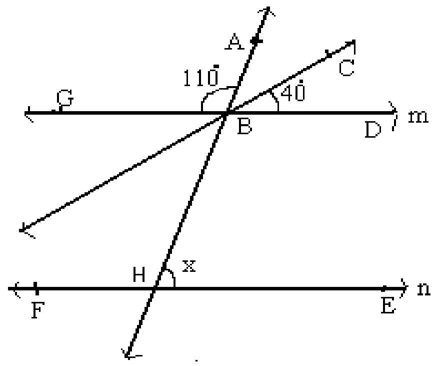
Question 10

m and n are parallel lines.

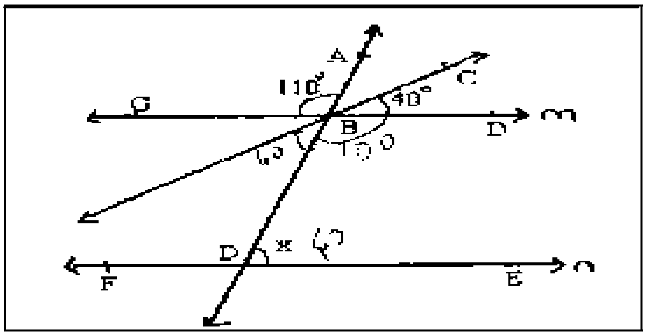
m(CBD)=40º and

m(ABG)=110º.

Find m(BHE)=x?



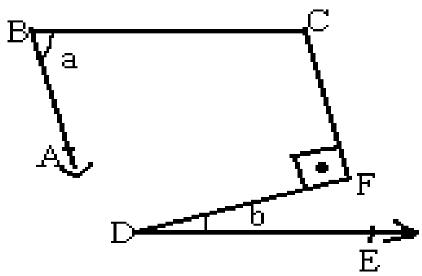
In this question students must use vertical angles, alternating interior angle and supplementary angle properties. Student H and A followed the correct method and found the solution. Student L used vertical angles property correctly for angle 110 but not for 40. Then he used alternating interior angles property incorrectly.



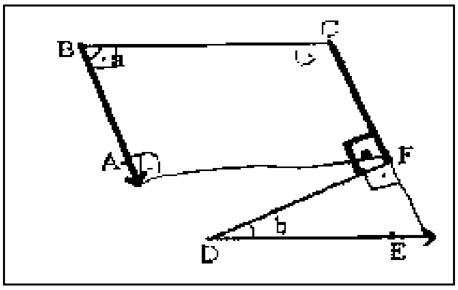
Student L

Question 11

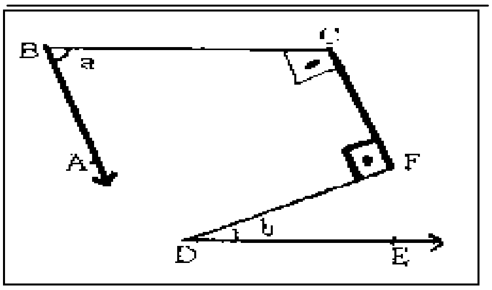
[BA // [CF] and [BC]// [DE
Find the value of a+b.



In this question students must draw a parallel line from the point of F to [BC] and [DE. Then they must use interior and supplementary angles which are not opposite of each other in a parallelogram. Only student H solved the question correctly. Student A and L could not solve the question. But they considered that angle F and C are equal.



Student L

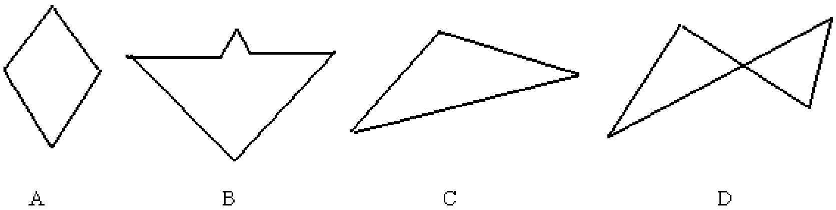


Student A

Triangles

Question 12

Which of the shape or shapes are triangle ? Explain your reason.



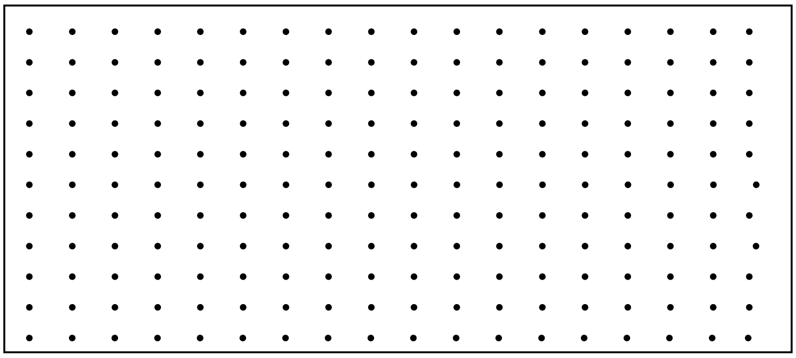
Triangle is the union of three distinct closed line segments determined by three concollinear points (Rockswold, Hornsby, and Lial, 2000). All students gave the correct answer that shape C is the only triangle. An example of the episode given by the students is presented below.

H: *Triangle is a shape that has three sides and three corners. Shape C is a triangle. If we think shape D by one by, we can see two triangles; but we take shape as whole, shape D is not a triangle. Shapes A, B are not triangles, too.*

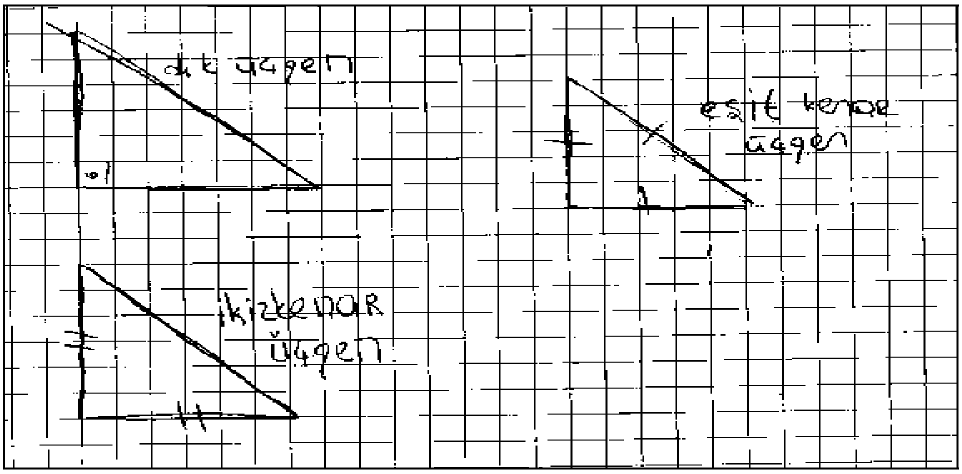
Question 13

Draw the given triangles on the geoboard.

a) Equilateral triangle b) Isosceles triangle c) Right Triangle



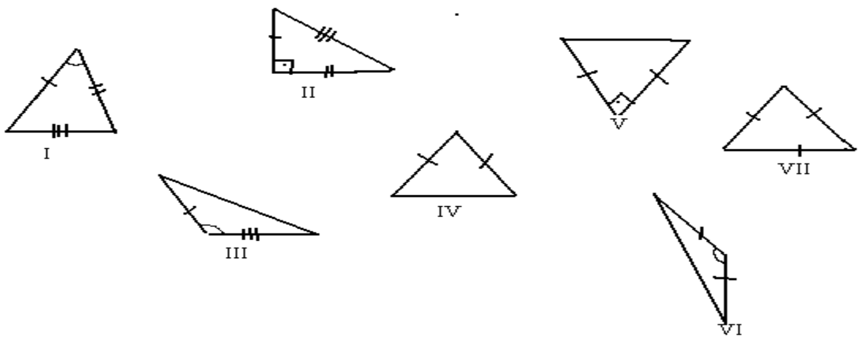
All students knew the side properties of these triangles so they drew all the triangles by pointing out their side properties on the figures drawn. They, however, did not put much attention to the equality of the length of the sides in their drawings. The reason might be that equal sides are shown in lessons by putting similar signs on these sides without using ruler. Moreover, they thought that they can constitute an equilateral triangle by only specifying the equality of the sides without paying attention to the angles. For example, their equilateral triangle have a right angle but right triangle cannot be an equilateral triangle.



Student H

Question 14

Please match the triangles that you think they are same with respect to their properties. Explain your reason.



These given triangles can be matched with respect to their sides and angles. According to the sides, triangles are scalene, isosceles and equilateral triangles. With respect to angles, they are acute, obtuse and right triangles.

Student H matched triangles correctly but mostly with respect to their sides.

> *H: Triangle I and III are scalene triangles, II and V are right triangles, IV, V and VI are isosceles triangles. III and VI are obtuse triangles. I*

can not match VII because there is no equilateral triangle.

The above extract shows that student H, however, did not think that the right triangle II is also a scalene triangle, and equilateral triangle VII is also an acute triangle. In addition, she did not consider that scalene triangle I and isosceles IV are also acute triangles.

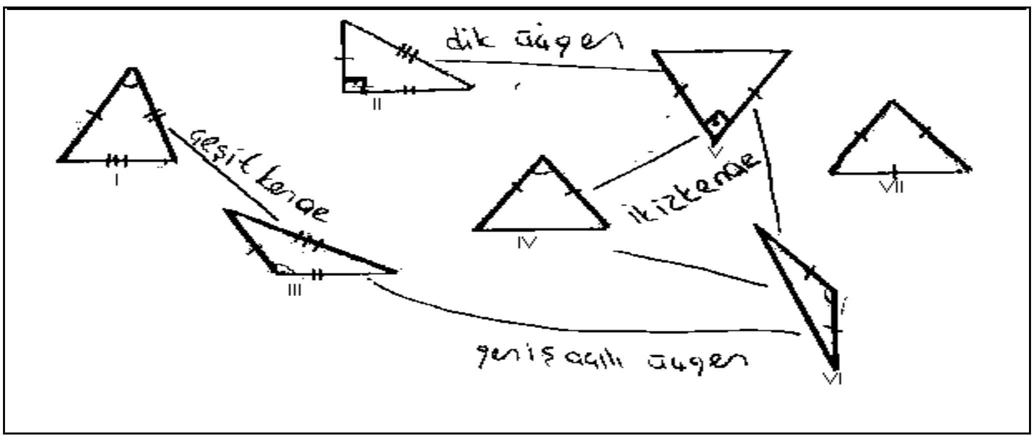
Student A also gave the correct answers but there was some missing matching. She could not identify the scalene triangles, and obtuse and acute triangles.

A: II and V are right triangles; IV, V and VI are isosceles triangles and VII is a equilateral triangle. I do not know the others.

Like Student A, student L gave the correct answers but there was some missing matching. He could not identify obtuse and acute triangles.

L: I, II and III are scalene triangles; II and V are right angles and IV, V and VI are isosceles triangles.

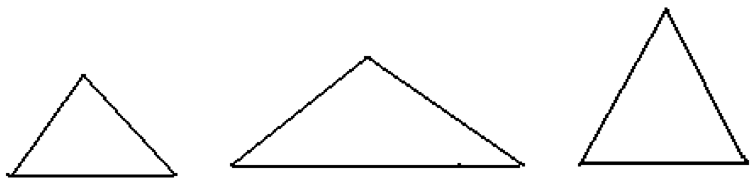
It is evident that students mainly match the triangles according to their sides except right triangle.



Student H

Question 15

A triangle any two of whose sides have equal lengths is called an Isosceles triangle. Three isosceles triangles are given below.



Which of the statement is true for every isosceles triangle?

a) Three sides have equal length.
b) One side of the length must be two times.
c) There must be any two angles that have equal measure.
d) Measure of three angles must be equal.
e) None of the statements are true.

All students gave the correct answer that statement c is true for every isosceles triangle.

Question 16

A triangle is a polygon with three sides. In a triangle ABC all sides are equal, i.e. , [AB]=[BC]=[AC].

The statement: All the angles in the triangle are also equal, i.e., m(A)=m(B)=m(C) is;
True / false / another answer. Explain your answer.

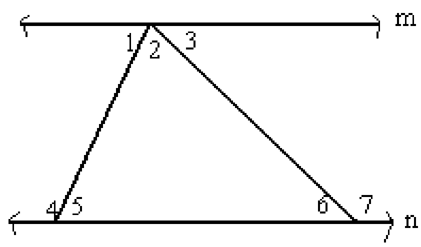
All students selected the true choice. Students explained their answers correctly.

H: This statement is true because if three of the sides have equal length, three of the angles must be equal .

A and L: Yes , this is true because according to this statement this triangle is a equilateral triangle.

As can be seen from the above extracts, students can parrot the critical attributes of equilateral triangles but they do not pay attention while drawing the figures as in (question 13).

Question 17



Which of the statement or statements are true?

Explain your reason. (<1: m(1))

a) <4=<2+<6

b) <3=<2+<5

c) <1+<2+<6=180°

d) <4+<1=180°

e)<7=<2

f)<2+<6=180°

In order to answer this question, students must know the exterior angle theorem, alternating interior angles, the sum of the interior angles of a triangle, and the measure of a straight angle.

Student H gave the correct answer that (a), (c) and (d) are true by giving all the correct explanations.

Student A could not define exterior angle theorem so she could not determine correct answer (a) related to that theorem. She, however, could see alternating interior angles in c but not in d.

Student L tried to answer the question by guessing the measures of angles.

L: (a) 4 is an obtuse angle so it must more than 90, but 4 and 6...,I do not know

(b) 3 is a acute angle so it can not be more than the sum of 2 and 5

(c) this can be true.

I: Why?

L: ....

(d) I do not know

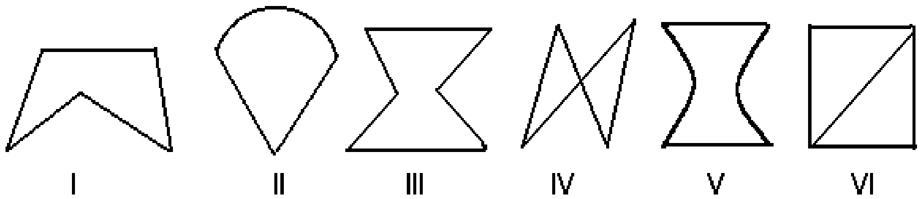
(e) 7 is an obtuse angle, 2 can be a right angle or less, it does not given

(f) it can not because if we take 5, it will be 180.

Polygons

Question 18

Which of the figure or figures are polygons? Explain your reason.



Polygon is a simple closed curve composed of line segments (Musser and Trimpe, 1994) or polygons are figures formed by joining segments at their endpoints, if the segments do not intersect at any other points (Bank, Posamentier and Bannister, 1972). The segments become the sides of the polygon.

Student H gave the answer that all the figures are polygons. When she was asked why they are polygons, she responded as:

H: They have two, three or more than three angles and sides. Thus triangle is a polygon, too. I is a polygon, omit II, III is a polygon and, IV and VI are polygons.

I: What about II and V?

H: Yes, they must be polygons because there are angles and sides.

Although she had doubt for shape II and V, she accepted them as polygons by thinking that they have angles and sides. It is apparent from her explanations that she does not seem to know that polygons compose of lines and an angle is formed by rotating a ray about its end points. She also did not differentiate the intersect lines at figure IV and VI.

Student A was aware of the fact that polygons compose of lines. But like student H she did not recognise that figures IV and VI could not be polygons because of the intersecting lines.

> *A: I do not remember the definition of polygon. I, III and IV are polygons because they are formed by lines, II is not because its side is not a line. I do not have decision for VI.*

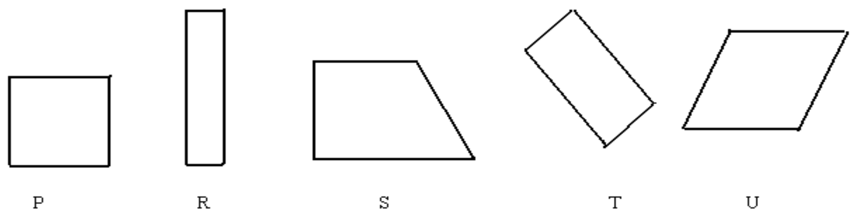
Student L responded that all the figures are polygons. His justification connected to the sides but lacked any reference to lines and non-intersecting lines.

> *L: Polygon must have more than three or more than four sides. I mean, it does not need a regular shape but it must have a few angles. I think, all shapes are polygons.*

As defined previously, *closed curve composed of line segments* and *joining line segments at their end points without intersecting at any other points* are critical attributes for classifying instances as positive or negative concept examples of polygons. Here all students did not consider the attribute - *the segments do not intersect at any other points other than its end points*. Students H and L also did not consider another attribute – *polygons are formed by line segments*. It is apparent that the students' concept image on polygons includes only some attributes of the definition of polygons.

Question 19

Which of the shape or shapes are rectangle? Explain your reason.



Rectangle is defined to be a quadrangle with four right angle. Square is also a rectangle, having congruent sides (Musser and Trimpe, 1994).

All students gave the correct answers that figure R and T are rectangles. They, however, did not choose figure P as a rectangle as it is a square. That is, students can identify the prototypical rectangles but they can not identify the specific form of a rectangle, which is a square.

H: Rectangle is a polygon with four sides and four corners, but all the length of the sides are not equal, reciprocal parallel sides are equal. Then, R is a rectangle, P is a square, S is trapezoid because reciprocal sides are not equal, U is not a rectangle. Is T a rectangle? One second(....) yes, but it does not stay very straight, it looks like(...)

I: Must it be straight?

H: No, this is not a provision, it can be a rectangle, am I making a mistake?

I: Ok, what is the difference between a square and a rectangle?

H: When we divide the square by drawing the medium, a isosceles triangle occurs; but if we divide rectangle, the length of sides are not equal. I think..

As can be seen from the above extract, the orientation of figure T also caused uncertainty for student H.

L: R and T are rectangles, P is a square

I: What are the properties of a rectangle?

L: Two sides are equal, other two sides are not. I mean it has two parallel sides and two different parallel sides. All of the angles are right angles.

Student A, however could not name the trapezoid and used the name polygon instead. In addition, she regarded figure U as a plane. This also shows that figure like U is considered as a prototypical example of a plane.

A: R and T are rectangles, U looks like a plane, S is a polygon probably, and P is a square.

I: What are the properties of a rectangle?

A: Reciprocal sides are equal, two short and two long sides...

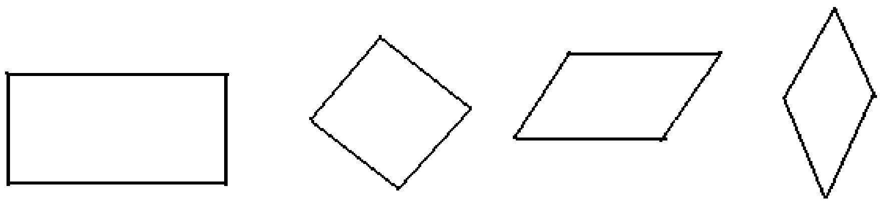
I: Ok, What about square? Its reciprocal sides are equal, too.

A: But, all the sides of a square are equal, in rectangle only two reciprocal sides are equal. In square four sides are equal, in rectangle they are separately equal.

As defined previously, *quadrangle* and *four right angles* are the critical attributes for classifying instances as positive or negative concept examples of a rectangle. The students' definition of rectangle included the critical attributes as well as the non-critical attribute. The figure drawn while introducing rectangle, two short sides and two long sides, has been found to be important in conceptual judgment. The figure drawn includes the critical attribute (four right angle) and non-critical attribute (two short and two long sides). The figure therefore can not be considered as a criterion for classifying instances as positive or negative concept examples of rectangle for all cases.

Question 20

Which of the shape or shapes are square? Explain your reason.



F G H L

A square is a quadrangle with all sides are congruent and four right angles (Musser and Trimpe, 1994). A square is also a rhombus and a parallelogram.

Student A and H gave the correct answer that figure G is the only one which is a square.

> *A: G is a square, I think L is a square, too.(....) but no, no...all four angles of a square must be equal, angles of L are not equal.*
>
> I: Ok, what is L?
>
> A: It can be a parallelogram

Further, Student H thought figure H as a rectangle rather than as a parallelogram as it has two equal short and long sides. This apparently indicates that students sometimes could not apply some critical attributes (e.g four right angles for rectangle) when choosing examples.

> *H: F is a rectangle, G is a square, H is a rectangle because all sides are not equal, L is not a square, I am not sure but we call it a kite.*

Student L chose figure L as well as figure G since “if we turn L, it look like a square, too”. This student was not aware of that the angles of figure L are not right angles.

As defined previously, *quadrangle, all sides congruent* and *four right angles* are the critical attributes for classifying instances as positive or negative concept examples of a square. It is apparent that students H and A used these critical attributes but student L used *four right angles* and *quadrangle* critical attributes not *all sides congruent* while identifying a square.

Question 21

Which one of the statement is true?

a) All the properties of a rectangle are also valid for all squares.

b) All the properties of a square are also valid for all rectangles.

c) All the properties of a rectangle are also valid for all parallelograms.

d) All the properties of a square are also valid for all parallelograms.

e) None of the choices are true.

All the properties of a rectangles, parallelograms, and rhombuses also apply to squares (Musser and Trimpe, 1994).

All students could not give the correct answer that all the properties of a rectangle is valid for all squares. Student H thought that they must be different as their names are different. This indicates that assigning different names to the concepts prevents students to connect relation among concepts. This student, however, considered other properties of the figures such as area and circumference.

H: (a) the perimeter of a rectangle is total of the sides and square is, too. Area of them are the same, too. If all the properties of a rectangle were valid for a square, there would be no difference between them. Thus, this alternative can not be true; (b)Because of the same idea, this can not be true; (c)False because we find their areas in different ways; (d)This is false, too. Actually, if we think that their properties were the same , there would not be any difference between them; (e)True

I: Do you think there are differences between them?

H: Yes, but I do not know what they are.

The responses of student L for each alternative confirmed that non-critical attributes hinder the identification of concept examples. For example, two short and two long sides for rectangle, not having right angles for parallelogram, and not all sides congruent for parallelogram.

L: (a)False because their length of sides are different; (b)False because all the sides are equal; (c)I am not sure. Rectangles have right angles but I suppose that parallelogram has two acute and two obtuse angles; (d) False because parallelograms can have long sides; (e) Then, this is true.

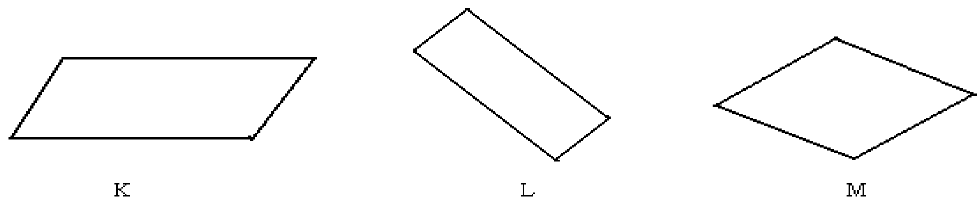
Similarly, students A confirmed that non-critical attributes hinder the identification of concept examples.

A:(a) False because a square has congruent sides but a rectangle has two short and two long sides; (b) This is true because they have four sides and their all angles are right angles; (c)False because their angles are different. A rectangle has right angles but a parallelogram does not; (d)False , the same thing is valid for square and parallelogram.

It is apparent that non-critical attributes and assigning different names to the concepts causes prototypes.

Question 22

Which of the shape or shapes are parallelogram? Explain your reason.



A parallelogram is a quadrilateral in which both pairs of opposite sides are parallel (Banks, Posamentier and Bannister, 1972). According to this definition, every rectangles, squares and rhombuses are parallelogram.

Student H and L answered correctly that K is a parallelogram. They, however, commented that a rectangle and a square are not a parallelogram as they have right angles.

> *H: Parallelogram is a polygon that its reciprocal sides are parallel. K is a parallelogram because its sides are parallel. L is a rectangle not a parallelogram because it has right angles, M is not a parallelogram, it seems like a square from here but a diamond-shaped square.*
>
> *I: Ok, how can you differentiate a rectangle from a parallelogram? Also rectangle has parallel sides.*
>
> *H: Yes, they have parallel sides, but I do not know the difference between them.*

Further, student L thought figure M as a parallelogram as it does not have right angles.

> *L: K is a parallelogram, L is a rectangle because its angles are right angles. M can not be a parallelogram.*
>
> *I: What is it then?*
>
> *L: It looks like a square, but the angles can not be right angles. Then, it must be a parallelogram, I think.*

As seen from the above extracts, student H and L did not know that a rectangle is also a parallelogram.

Student A gave the correct answer that all figures are parallelograms.

As defined previously, *quadrangle* and *parallel opposite sides* are the critical attributes of a parallelogram. The students' identification of a parallelogram included the critical attributes as well as a non-critical attribute. The figure drawn while introducing parallelogram, *parallel opposite sides not having right angles*, has been found to be important in conceptual judgement. The figure drawn includes the critical attribute (parallel opposite sides) and non-critical attribute (not having right angles). The figure therefore is considered as a criterion for classifying instances as positive or negative concept examples of parallelogram. This indicates that this non-critical attribute cause difficulty in conceptual judgement.

4.2 Discussion and Conclusion

The data obtained from this study confirm that prototypes or figures, assigning different names to the concepts, and the non-critical attributes of the concepts play an important role in geometrical reasoning. The results also confirm that geometrical concepts are mainly acquired by means of figures.

Even the definition of a concept defines the boundaries of the concept as well as its critical attributes, some more weighted drawn figures are more central to learning than the definition. Namely, students' concept images are elaborated from figures interfering with the concept definition. Consulting the figural examples not the definition cause a fixation on the identifying of concept examples. This consulting procedure leads to the desirable results in some cases but not in all. These more weighted figures, called prototypes, have been found to be important in conceptual learning. This finding supports the findings of previous studies (Hershkowitz, 1989; Hoffer, 1983), which provided evidence that the shape and the self attributes of the prototype are the criterion for prototypal judgement. As far as geometry is concerned, from the point of view of figural concepts, a new harmony between the figural and the conceptual aspects must be achieved, which takes into account the theoretical constraints of figures.

The finding of this study also appear to suggest that naming the concepts differently leads erroneous conclusions. In other words, students try to impose the shape of the prototype on the name of the concept. This prevents students to connect relation among geometric figures and also explains students' resistance to hierarchical relations among quadrilaterals. For instance, a concept or a figure may have more than one name – a square is also a rectangle and a parallelogram. Students does not conceptualize that this kind of nesting can occur. This finding agrees with those of Burger and Shaugnessy (1986), Hershkowitz(1989), Hoffer

(1983), Matsuo (2000), and Wilson (1983), who reported that students do not distinguish between two concepts of the geometric figures based on their differences and similarities.

A point we would like to stress is the importance of developing connections between figures and their properties and forming hierarchical relationships between different types of quadrilaterals. De Villiers (1994) and De Villiers (1998) stated an advantage of hierarchical definition for a concept is that all theorems proved for that concept then automatically apply to its special cases. It is very clear that these difficulties occur because the necessity and the importance of hierarchical classification are not applied in classes effectively and this must be stressed in National Curriculums. The hierarchical order must be in the sequence of parallelogram, rhombus, rectangle, and square rather than square, rectangle, parallelogram, and rhombus.

The findings from this study also appear to suggest that students consider figures as different when the change of the position are apparent. This finding is consistent with those of Prevost (1985), and Burger and Shaughnessy (1986), who reported that students include irrelevant attributes in case of the orientation of the figure. Drawing regular figures in teaching are likely to have affected students' learning.

The comparison of these three level students revealed not much difference on understandings of polygons and quadrilaterals. This showed that prototypes or figures, the difficulty in understanding assigning different names to the concepts, and considering non-critical attributes of a concept as a critical attribute are quite prevalent among all level of students.

CHAPTER V

RESULTS

Results of the pre, post, delay-post tests of GPT with CAS, and the results of the correlation analysis between GPT and CAS are given in detail in this chapter. In addition, the analysis of the open-ended question in CAS and interviews are presented.

5.1 Results of the Geometry Performance Test

Geometry Performance Test was administered as a pre-test, post-test, and delay-post test to both EG and CG students.

Descriptive statistics for the pre-GPT, post-GPT and delay-GPT for EG and CG are given in Table 5.1.

The Box-and-Whisker plots of the pre, post and delay-post GPT scores for EG and CG is given in Figure 5.1.

Frequencies and percentages of EG and CG students' correct answers in Pre, Post and Delay GPT are presented in Appendix D.

Table 5.1: Descriptive Statistics for pre-GPT, post-GPT and delay-GPT scores for the EG and the CG.

	Pre-PT		Post-PT		Delay-PT	
Statistics	**EG**	**CG**	**EG**	**CG**	**EG**	**CG**
N	31	32	31	32	31	30
Mean	42.9	43.25	59.8	48.4	55.06	47.4
Std. Error of Mean	1.65	1.25	1.65	1.25	1.99	1.69
Median	43	43.5	60	50	55	48
Mode	43	40	52	56	55	51
Std. Deviation	9.25	7.07	8.41	6.27	11.08	9.3
Variance	85.6	50	70.74	39.28	122.79	86.66
Maximum	61	56	79	57	74	65
Minimum	26	29	46	34	33	29
Range	35	27	33	23	41	36
Skewness	0.35	-0.087	0.43	-0.04	-0.18	0.42
Quartile I	35	40	52	43	45	40.75
Quartile II	43	43.5	60	50	55	48
Quartile III	49	47	64	54	63	52.75

Not: Maximum score in the Performance Test is 82.

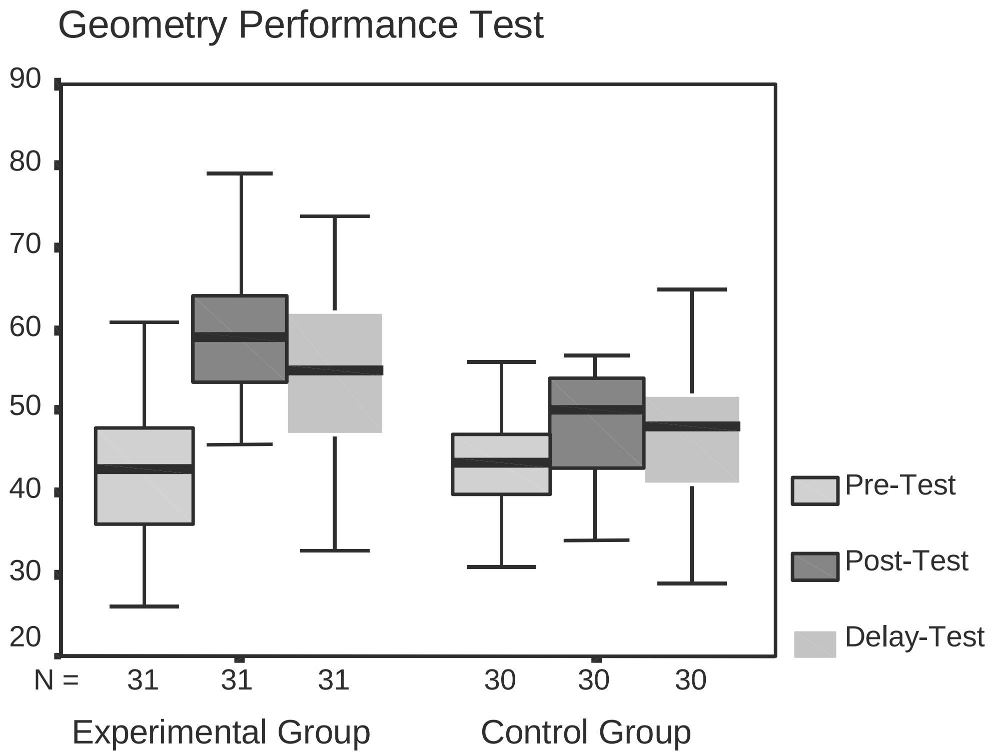


Figure 5.1: Box-and-Whisker plots of pre, post and delay-post tests for GPT scores for EG and CG.

Independent samples t-test was carried out in order to examine whether there was a significant mean difference between EG and CG students' GPT scores prior to the instruction on geometry. The results showed that there was no significant mean difference between EG and CG with respect to the pre-test prior to the instruction of geometry ($t=-0.168$, $p=0.867>0.05$). This results also confirmed by the Effects Size (ES), ($ES= 0.04< 0.5$), as the ES less than 0.5 shows not a significant mean difference. The pre-test results indicated that both groups were equivalent in geometrical performance at the beginning of the experiment. When Appendix D was analyzed in detail, it was seen that, the frequency and percentages of correct and incorrect answers for each tasks in pre-GPT were nearly the same for EG and CG. One of the important point from this pre-GPT analysis is the percentages of the explanation items of the questions. Although the CG students' percentages of the correct explanations were not adequately high enough, they were higher than the EG students' percentages in all explanations except item 16expl. This result showed that the CG students' concept definitions and explanatory knowledge was better than the EG students' before the treatment.

Independent samples t-test was carried out in order to examine whether there was a significant mean difference between EG and CG students' GPT scores upon the completion the treatment on geometry. The results showed that there was a significant mean difference between EG and CG with respect to the post-test ($t=6.15$, $p=0.0<0.05$, $ES=1.55>0.5$). This means that the EG showed a test mean score that was significantly higher than the CG.

As seen from Appendix D and Table 5.1, the scores of post-GPT were prominently changed for both groups**.** Especially EG students showed a rising distinctly in correct answers percentages in all items except items 5d,14j,18f and 20b. Surprisingly the CG students also showed a falling in the same items except 18f but there was not seen a rising in item 18f. The most important rising in EG was seen on the explanation items of the questions. For example, the frequency of the number of correct answers of Q1expl., Q6expl., Q12expl., Q16expl., Q19expl. and Q22expl. was risen from 11 to 24, 1 to 18, 7 to 29, 7 to 23, 12 to 27 and 1 to 26 respectively. These percentages of the explanation items give some clues about the reason of these increases. When the students' written explanations on their papers were analyzed, it was seen that most of the EG students got rid of their prototypes by reforming their non-critical attributes. In item 19expl., before the treatment, the correct answer of this item was 12. Rest of these students defined a rectangle with two long and two short sides (non-critical attributes). After the treatment, 27 students in EG defined a rectangle with critical attributes that are four right angle and congruent sides. In item 22expl., before the treatment, only one student defined a parallelogram correctly. Rest of the students' identification of a parallelogram included the critical attributes as well as a non-critical attribute. The figure drawn includes the critical attribute (parallel opposite sides) and non-critical attribute (not having right angles). Item 22b shows that students' explanations were under the impression of non-critical attribute because they did not choose a rectangle as a parallelogram. Before the treatment, the number of correct answer of this item was 4 but after the instruction of dynamic computer instruction, the number of correct answer was 24. In spite of this, the CG students' definitions included explanations related to the prototypical rectangles after the treatment. These explanations showed that dynamic computer instruction have a significant effect on overcoming the prototypes.

In spite of the increasing in EG scores, the CG scores did not increase in the same degree of EG or they could not protect the exist percentages. For example, the frequency of the correct answer of Q8b was increased from 1 to 16. This was the highest difference in the CG scores.

Finally, the difference of the scores between post-GPT and delay-GPT were calculated in order to examine whether there was a significant mean difference on delay-GPT between EG and CG. When t-test was conducted with these scores, it showed that there was no significant mean difference between the EG and CG ($t=1.305$, $p= 0.197>0.05$). But when the independent samples t-test was carried out with delay-GPT scores, it was found that there was a significant mean difference between EG and CG with respect to the delay-GPT ($t= 2.92$, $p = 0.005 < 0.05$). The magnitude of the Effect Size ($ES=0.75>0.5$) also confirms this result. We conclude from these analysis that EG students achieved significantly better than CG students..

Figure 5.1 shows the changing of two groups' scores in delay-GPT obviously. The two groups means of delay-GPT were decreased. Nearly the frequency of the all items showed a falling. In spite of this reduction, the mean of delay-GPT in EG was significantly higher than CG. Furthermore, most of EG students kept their true definitions in the delay-GPT. We can conclude that from these results of the delay-GPT, dynamic computer instruction also raised scores on follow-up examination given several months after the completion of the instruction, but these effects were not as high as the immediate effects of dynamic computer instruction.

From the data and it's analysis, the conclusion drawn that seventh-grade students in the EG had a higher performance level in learning geometric concepts using GSP, and a better retention level.

5.2 Results of the Computer Attitude Scale

Frequencies and percentages of students' attitude scores for each item in CAS are given in Table 5.2. Descriptive statistics for the AS scores for EG are presented in Table 5.3.

Table 5.2: Frequencies, Percentages and Means of AS's Items.

Items	S C O R I N G					$\bar{x}$
	0	1	2	3	4	
1	3 (9.7%)	0 (0%)	6 (19.4%)	7 (22.6%)	15 (48.4%)	3
2	3 (9.7%)	5 (16.1%)	7 (22.6%)	8 (25.8%)	8 (25.8%)	2.42
3	0 (0) %	1 (3.2%)	3 (9.7%)	17 (54.8%)	10 (32.3%)	3.16
4	1 (3.2%)	1 (3.2%)	7 (22.6%)	12 (38.7%)	10 (32.3%)	2.94
5	9 (29%)	1 (3. 2%)	9 (29%)	5 (16.1%)	7 (22.6%)	2
6	0 (0%)	5 (16.1%)	7 (22. 6%)	3 (9. %7)	16 (51.6%)	2.97
7	4 (12.9%)	2 (6. 5%)	6 (19.4%)	8 (25.8%)	11 (35.5%)	2.65
8	3 (9.7%)	0 (0%)	5 (16.1%)	9 (29.0%)	14 (45.2%)	3
9	1 (3.2%)	2 (6.5%)	7 (22.6%)	12 (38.7%)	9 (29. 0%)	2.84
10	3 (9.7%)	3 (9.7%)	3 (9.7%)	17 (54.8%)	5 (16.1%)	2.58
11	4 (12.9%)	2 (6.5%)	3 (9.7%)	11 (35. 5%)	11 (35. 5%)	2.74
12	4 (12.9%)	2 (6.5%)	6 (19.4%)	11 (35.5%)	8 (25.8%)	2.55
13	3 (9.7%)	2 (6. %5)	10 (32.3%)	8 (25.8%)	8 (25.8%)	2.52
14	4 (12.9%)	3 (9. 7%)	4 (12.9%)	14 (45. 2%)	6 (19.4%)	2.48
15	5 (16.1%)	4 (12.9%)	2 (6.5%)	12 (38.7%)	8 (25.8%)	2.45
16	1 (3. 2%)	5 (16.1%)	8 (25.8%)	14 (45.2%)	3 (9.7%)	2.42
17	4 (12.9%)	2 (6.5%)	5 (16.1%)	16 (51.6%)	4 (12.9%)	2.45

Table 5.3: Descriptive statistics of the CAS scores for EG.

Statistics	EG
N	31
Mean	45.16
Std. Error of Mean	2.62
Median	49
Mode	49
Std. Deviation	14.58
Variance	212.54
Minimum	5
Maximum	67
Range	62
Skewness	-.91
Quartile I	35
Quartile II	49
Quartile III	56

Note: Maximum score is 68.

When Table 5.3 was analyzed in detail, the following results was occurred. First of all, most of the students have a positive outlook towards computer instruction because while the maximum score of the scale is 68, the mean of it is 45.16. Frequencies and percentages of students' attitude scores for each item in CAS confirm the same result. For example, in item (14), "In view of the amount I learned, I would say that computer instruction is superior to traditional instruction", 65% of the students were agree or strongly agree with this statement although 30% of them were disagree or strongly disagree with it. Another item (3) is, “ As a result of having studied some material by computer instruction, I am interested in trying to find out more about the subject”. For this item, 87% of the students were agree but only 3% of them were disagree with this item. Item 8 is a negative statement and it has similar percentages. The statement is “Computer instruction is an inefficient use of the students’ time ”. 79% of the students were disagree to this statement and only 9% of them were agree with this statement. From these results, we can say that students gained positive feelings and decisions towards computer instruction and they preferred computer instruction to traditional instruction.

In CAS, one multiple choice question was posed to students. The question was. “How long do you feel you can work efficiently with computer instruction in one sitting?”. The frequencies of the answers given to this question is presented in Figure 5.2.

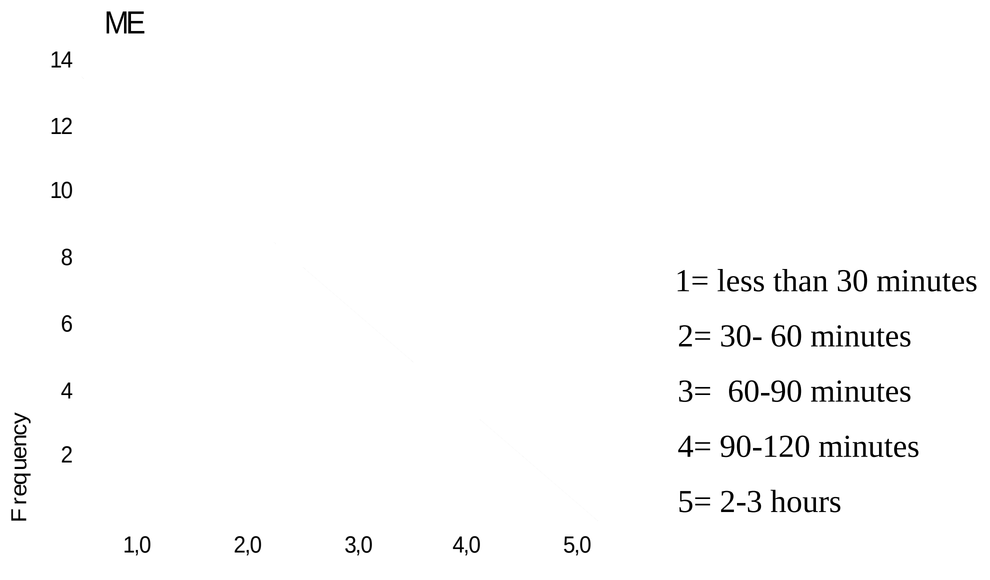


Figure 5.2: Answers given to the question “How long do you feel you can work efficiently with computer instruction in one sitting?”

As seen in Figure 5.2. most preferred answer 30-90 minutes also suits to time of two lessons which is 80 minutes.

5.3. The Relation of Attitude Towards Computer Instruction and Performance Test Results

Table 5.4 gives the correlation between the post-GPT, delay-GPT and CAS scores. As can be seen from the table, the correlation between post-GPT and delay-GPT, and delay-GPT and CAS were significant.

Table 5.4: Correlation between the GPT and CAS

	Post-PT	Delay-PT	CAS
Post-PT		0.372*	0.166
Delay-PT			0.370*
CAS			

* Correlation is significant at the 0.05 level (2-tailed)

In addition to this correlation, we conducted the scatterplot matrix in order to get rich descriptive picture of these relationships.

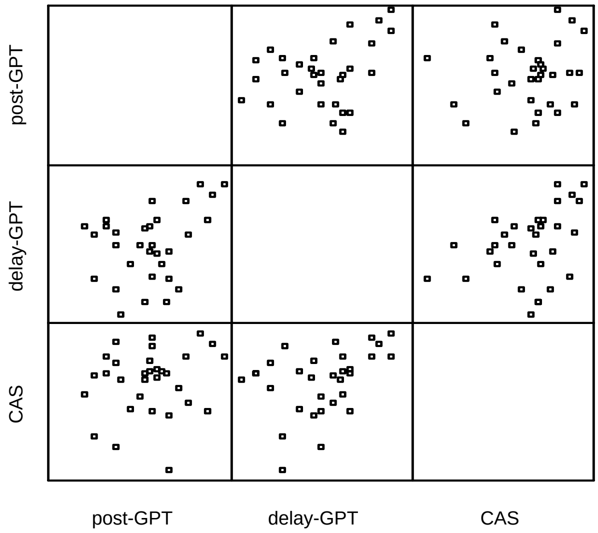


Figure 5.3. Relationships among post-GPT, delay-GPT and CAS.

There is a positive correlation between post-GPT and delay-GPT, and delay-GPT and CAS. Also, there is a weak positive correlation between post-GPT and CAS. From this result, we conclude that the students who have high attitude towards computer got better results in the delay-GPT than the post-GPT.

5.4 EG Students' Thoughts and Feelings About CBL

At the end of the CAS four open-ended questions were posed to the students to get their thoughts and feelings about computer based instruction. Adding to these question, researcher made interviews with three students from the EG for the same purpose. In some of the questions, we got the same or close answers so we analyzed open-ended questions and interviews here together.

Here the responses related to each question are presented and interpreted separately and some excerpts from individual transcripts are given.

Question 1: How does computer-based learning be useful to you in geometry?

All students. except two students. were sure that computer-based learning was useful for them. Two student claimed that CBL was not useful. But. they also pointed out that the figures seen on computer screen were permanent on their mind.

Students pointed out the benefits of CBL in different ways. These benefits are listed below:

a) CBL is very amusing and studying with it very easy.

b) CBL provided learning geometry fast and practical.

c) Learning and comprehending geometry and solving questions got easy with GSP.

d) Learning basic concepts with seeing on the computer screen was more permanent.

e) There was no time missing. Because of this, more knowledge about geometry was obtained with GSP in a short time.

f) GSP had colourful geometric shapes and animations. These were interesting and beautiful.

g) GSP helped by measuring angles and doing calculations.

In addition, during the interview we got some different conclusions from the students. One of the student explained the benefit of CBL as:

> *"I did not like geometry before. But after I learned lessons from the computer. I like it because I saw that I can solve the questions easily. Now. I like geometry very much".* (Student 1)

> *" I could not solve the geometry problems before and I could not comprehend completely the figures. The operations were difficult for me. There was an image. but I could not understand them I think...... . In spite of these, we can see the figures on the screen. I do not forget them. Geometry lessons are more easier now...* (Student 2)

Question 2: What kind of revisions do you suggest to computer-based lessons of geometry?

Most of the students from EG claimed that they were pleased from the CBL. They did not give any suggestion. Addition to this, some of the students gave different and interesting suggestions about GS. They proposed adding a voice to GS which can warn students' errors and affirms students' truth. By this way, students can understand more easily and GSP can get students' attention.

> *"I am very please from these lessons. We liked either computer or geometry. I would like to use computer at numerical lessons" (Student 1).*

Question 3: What kind of revisions do you suggest to geometry lesson as a whole?

Some of the students from EG did not give any suggestion to geometry lessons. Some of them wanted to continue the computer-based lessons. Most of the students wanted to solve more exercises in the lessons and they wanted to learn more solving ways. Moreover, they stressed that they did not like long answered questions. They wanted easiness of solving at answering.

Question 4: What are the most important factors that effect your studies in geometry?

Most of the students complaint from drawing figures at geometry lessons using ruler and protractor. They saw drawing lost of time. They also claimed that they studied geometry much but they could not solve questions. By this way they did not like geometry lessons. Students gave similar answer in the interview.

> *" Using the ruler*, protractor *was on the board was difficult also on the notebooks. I do not like the. Sometimes while I drawing the figures, I could not listen the teacher. But Shetchpad does operations by itself, calculate the angles and shows us".(* Student 3)

CHAPTER VI

DISCUSSION, CONCLUSION AND IMPLICATIONS

6.1 The Development of Students' Understanding of Lines, Angles and Polygons

The main objective of this study was to investigate whether the use of Geometer's Sketchpad-under dynamic instructional environment-would significantly improve 7th grade students' understandings of lines, angles and polygons.

The treatments on both groups were conducted at the same time. The lessons in EG featured computer-based teaching method. The EG training was accomplished through the use of a series of Sketchsheets. However, the CG students were not engaged in any computer activities. They were thought by the traditional teaching method in classrooms.

Pre Performance Test results yielded that EG and CG students' mean scores did not differ significantly. Thus, it can be said that both groups were equivalent in performance on geometry at the commencement of the experiment.

A comparison of the pre-and post-test means of the students indicates that the treatment resulted in marked improvement in their achievement in lines, angles, and polygons in EG. Similarly, Post Performance Test results revealed that EG students' performance was indeed enhanced by the GSP treatment. This result revealed that dynamic computer instruction have facilitated to the students' better understanding of the geometric concepts thought. Working in this environment helped students build increasingly sophisticated mental models for thinking about geometric shapes. Such work also encourages and supports students' development and understanding of the property-based conceptual system used in geometry to analyse shapes. It encouraged students to move to higher levels of geometric thinking instead of having to memorise a laundry list of shape properties. The dynamic computer instruction involves students as conceptualising participants, not massive spectators in the process of doing geometry. This is supportive of the NCTM on the use and participation of the computers into middle and high school classes. NCTM (1991) recommended strongly the use of computer and technology for independent exploration. This finding support the findings of previous studies (Battista, 2002; Chazan, 1988; Choi-Koh, 1999; Dixon, 1997; Kakihana and Shimizu, 1994; Yusuf, 1991).

Adding to these results, analysis of the students' explanations given in some of the questions were indicated that EG students' understanding was deeper in content than CG. One of the most important result of this study is that students instructed with dynamic geometry environment, got rid of the prototype phenomena. From the EG students' written responses and explanations in pre and post tests, it was seen that there is a crucial difference in students' definitions and explanations. Although the definitions in pre-test included non-critical attributes of shapes, most of the students' definitions in the post-test were included critical attributes not non-critical attributes. This difference base on the feature of visualisation of GSP especially the distinction between a drawing and a constructing. For example, in a classroom, when a teacher draws a figure on the board and informs a class the figure is a parallelogram ABCD, the teacher is trying to tell the students " let ABCD represent a parallelogram, and let all the properties inherent in a parallelogram be attributed to figure ABCD".

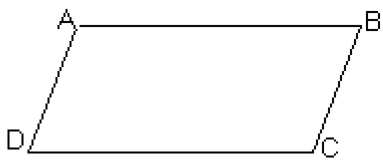


Figure 6.1: A figure which could represent a parallelogram

The figure that presented in Figure 6.1. is the common drawing of a parallelogram in geometry lessons. The students expect to understand this parallelogram is a generic parallelogram**,** and will remain a parallelogram no matter what its orientation or scale. As we said in pilot study**,** the figure drawn while introducing parallelogram, *parallel opposite sides not having right angles*, has been found to be important in conceptual judgement. Most of the students saw this parallelogram on the board did not accept right angled shapes (e.g. rectangle, square) as a parallelogram. This generic shape of parallelogram causes students to have prototypical shapes on their minds. But**,** GSP allowed students to play with figure, and build dynamic and flexible geometric models by dragging the shapes. Also they created, explored, manipulated the parallelogram and transformed this parallelogram to a rectangle or a square. Bu this way, they have discovered a special cases (e.g. rectangle, square) of the original construction of a parallelogram. GSP can be used in geometry classes as an in-class teaching help creating dynamic and productive three-way interaction between teacher, student, and computer (Hativa, 1984). By this way students make their own judgements and acquire their own conclusions and students became distant from the prototype phenomena.

Students in EG had difficulties in naming geometric shapes before the treatment. They had prototypical shapes on their mind, for instance, when the orientation of the shapes changed, they could not define them. But, during the dynamic computer instruction with GSP, students saw every orientation of the shapes by dragging. This "drag" feature allows users to modify the objects of the constructions. By this way, the students starting from the visual considerations of the geometrical shapes, had, towards end of the process, developed connections between the figures and their properties, and formed hierarchical relationships between different classes of shapes. This important result of the study supports that of Clements and Battista (1992), who reported that geometry software packages had a better knowledge of geometric concepts, and a richer understanding of conjecturing skills.

Delay Post Performance Test results showed that dynamic computer instruction have significant effect on students’ retention. Computer-based teaching raised scores on follow-up examinations given several months after the completion of instruction, but these retention effects were not as clear as the immediate effects of computer-based teaching. This results showed that EG students kept their knowledge after the treatment. This is consistent with findings from earlier studies (e.g., Kulik, Bangert, and Williams, 1983).

6.2. Students’ Attitudes Towards Computer Instruction

Attitude Scale Towards Computer Instruction was administered after the completion of the experiment to determine the attitude of the EG students towards computer based learning environment. In addition, interviews were conducted with three students from the EG in order to get their feelings about computer based learning environment. Analysis of students’ attitude scores and the interviews revealed that the students’ had high level of interest in learning geometry under the dynamic instructional environment and the use of technology.

Based on the interviews and classroom observations, some important information about the students’ feelings and decisions about the geometry lessons had got. The researcher noticed from these information, EG students were seldom bored with the topic at hand, whereas the CG students’ often displayed lack of interest and curiosity. It was also noticed from classroom observations that the overall behaviour and motivation of the EG was better than that of the CG. EG students mentioned that they liked from this study and enjoyed very much. Also, they wanted to continue the lessons with GSP. Skinner (1988) and Alkalay (1993) found similar results in the literature in support of current results.

In addition, the computer setting and dynamic environment seems to encourage good student behaviour. From the classroom observations, it was seen that students entered into the lessons continuously on time, they participated in activities willingly and they stayed after class sessions for further studies or for to examine the GSP in detail. It was also noticed that students' work become more accurate and their ability to express themselves correctly and improved briefly. Furthermore, unlike the traditional method, student-student and student-teacher communication allowed students to engage willingly in making conjectures, and validate answers.

6.3. The Relationship Between Students' Geometry Performance and Attitudes Towards Computer Instruction.

The findings from this study also appear to suggest that the students who had positive attitudes towards computer instruction achieved significantly better. In other words, the students who had more positive attitude toward geometry, showed a high performance in post-test also in delay-post test. Similarly, Munger and Loyd (1989) supports this finding that they found a significant relationship does exist between mathematics performance and attitudes toward technology.

Considering the all facts of this study, it appears that the usage of GSP have a positive impact on overall geometry achievement and students' attitude towards computer and geometry lessons. The result of this study indicates that using the GSP for independent exploration and investigation in elementary school geometry curriculum is an effective instructional tool. Finally, this study supports the use of GSP to improve basic geometric knowledge, and students' dispositions towards mathematics.

6.2. Implications

One of the main purpose of the geometry education is to develop pupils' visual awareness and spatial ability through consideration of figures, and to provide insight into the properties and interactions of these figures. Shoenfeld (1989) mentioned that "classroom culture" plays an important role in how students perceive and learn geometry. He proposed that students' beliefs of "what geometry is really all about." are determined by the daily practice of the classroom environment. For example, if students are only encouraged for quick algorithmic solutions, then students might believe that success in geometry has more to do with speed and memorisation than reasoning. But, if teachers believe that mathematics should be a "sense-making activity" (Shoenfeld, 1989), then classroom culture reflect this idea. Conjecturing, analysing, exploring, and reasoning should be daily routine in geometry lessons, and the GSP is an important vehicle of this; if implemented and transform to the classroom correctly.

To achieve these purposes it will take a tremendous effort on the part of the mathematics education community, since it will require a re-training of teachers and prepare more better and effective materials for the studies. As we saw in this study, class teacher did not see herself adequate for the computer lessons although she was taught to use the dynamic programme prior to the treatment. Because of this, this re-training is very important that will have a focus on both how to use technology and how make effective use of it in the classroom. This will require teachers to change what they are teaching and how they teach. Some of potential vehicles of re-training could be the summer programs, courses, workshops and conferences that teachers could attend to learn how to use technology and computers.

In order to gain more evidence on the effect of using GSP in the geometry classes, the following studies are offered:

- To compare groups of students over one year, include a large sample of students
- To show the effects of treatment and ability level on students' achievement in geometry
- To conduct this study for different subjects of mathematics

- To investigate the students' gained attitudes by the dynamic instructional environment
- To determine the how the amount of time spent utilising dynamic geometry software specifically affects the dispositions of students towards mathematics and technology.

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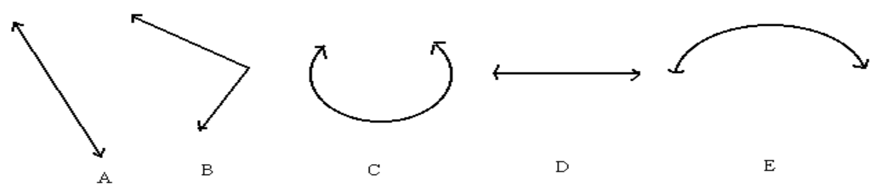
APPENDIX A

GEOMETRY PERFORMANCE TEST (GPT)

AD, SOYAD:

NUMARA: NO: YAŞ: CİNSİYET:

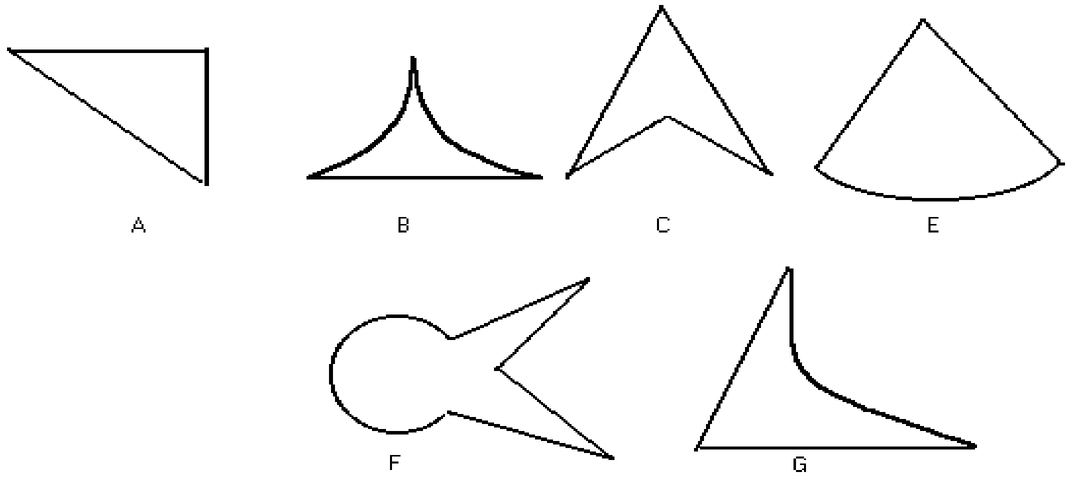
1.) a)Aşağıdaki şekillerden hangisi veya hangileri birer ‘doğru’ gösterir.
b)Cevabınızı açıklayınız.



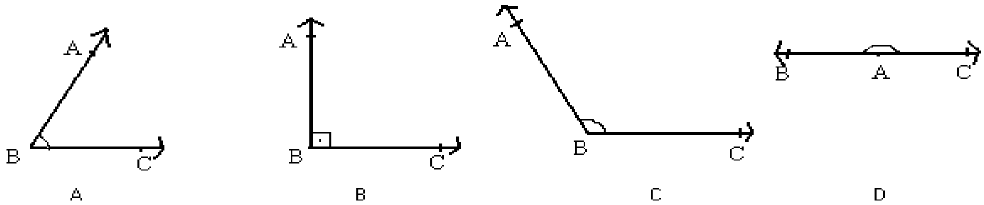
2.) Bir düzlemde iki doğru kaç farklı şekilde bulunabilir. Açıklayınız.

3.) Bir E düzlemi ile bir d doğrusunun. hiç ortak noktası yok ise bu iki şeklin birbirine göre durumunu açıklayınız.

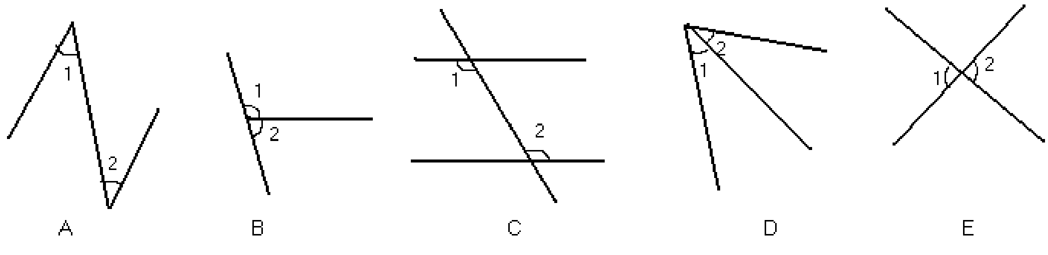
4.)Aşağıda verilen şekiller üzerinde yer alan <u>her bir açıyı</u> A harfi ile gösteriniz.



5.) Aşağıda verilen açıların türlerini belirtiniz.

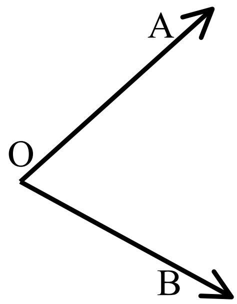


6.) Aşağıdaki açı çiftlerinden hangisi yada hangileri birer ‘ komşu açı’ gösterir.(açı çifti 1 ve 2)



Bir arkadaşınıza telefonda, bir çift komşu açıyı nasıl anlatırsınız veya açıklarsınız.

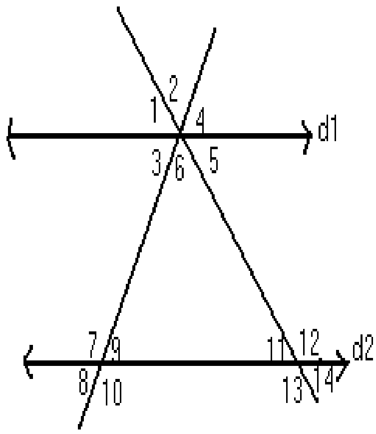
7.) Kenarları birbirinin zıt ışını olan açılara Ters Açılar, denir. Bu tanıma göre.,aşağıda verilen AOB açısına ters olan açıyı çiziniz.



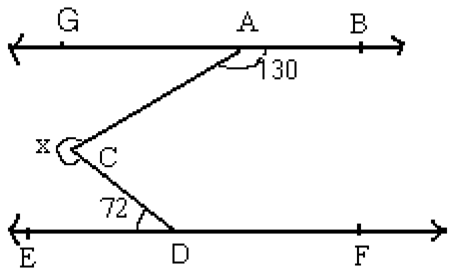
8.)Yandaki şekilde. d1 ve d2 doğruları birbirine paraleldir Buna göre;

a) Bir çift içters açı gösteriniz.

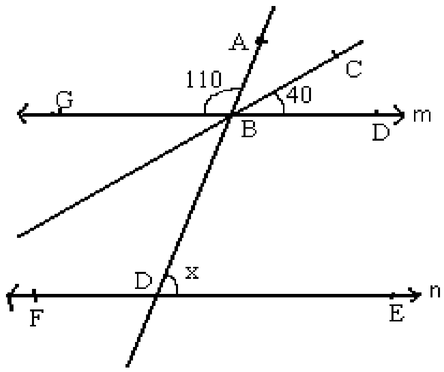
b)Açı 4 ile açı _______ bir çift dışters açıdır.



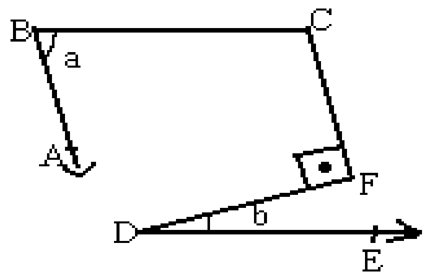
9.)Yandaki şekilde. d1 ve d2 doğruları birbirine paraleldir. s (CAB)=130º ve s(CDE)=72º olduğuna göre, x açısı kaç derecedir?



10.) m ve n doğruları birbirine paraleldir. s (CBD)=40º ve s(ABG)=110º olduğuna göre BDE (x) açısı kaç derecedir?

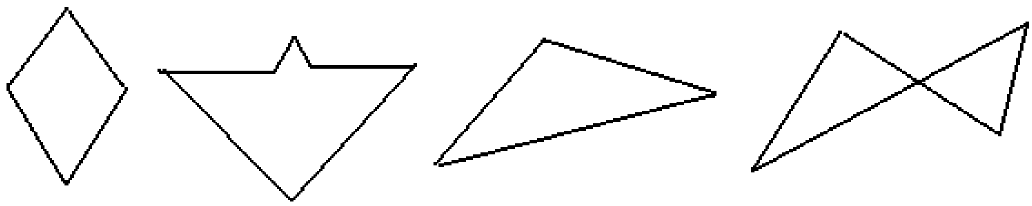


12) Yandaki şekilde [BA // [CF ve [BC]//[DE dir. Buna göre a+b kaç derecedir?



11.) a) Aşağıdaki şekillerden hangisi yada hangileri üçgendir?

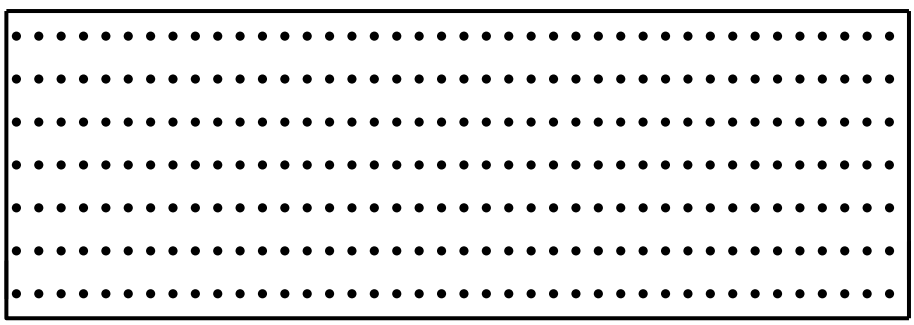
b)Neden?



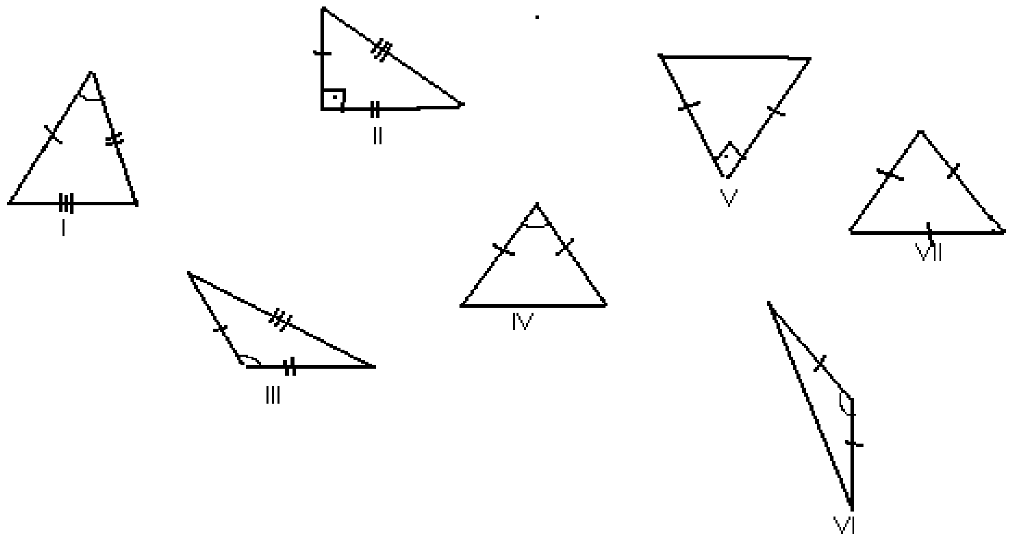
A B C D

13.) Aşağıda yazılı üçgen çeşitlerini tablo üzerine çiziniz.

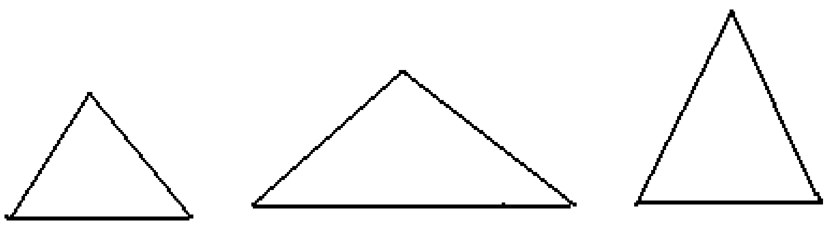
a) Eşitkenar üçgen b)Dik üçgen c) İkizkenar üçgen



14.) Aşağıda verilen üçgenlerden bazı özelliklerine göre aynı olduğunu düşündüklerini eşleştiriniz. Nedenlerini yazınız.



15.) İkizkenar üçgen.iki kenarı eşit uzunlukta olan üçgendir. Aşağıda üç tane ikizkenar üçgen verilmiştir.



Aşağıdaki seçeneklerden hangisi <u>her</u> ikizkenar üçgen için doğrudur?

a) Üç kenarı eşit uzunluktadır.

b) Bir kenarının uzunluğu. diğerinin iki katı olmalıdır.

c) Ölçüsü eşit olan en az iki açısı olmalıdır.

d) Üç açısınında ölçüsü eşit olmalıdır.

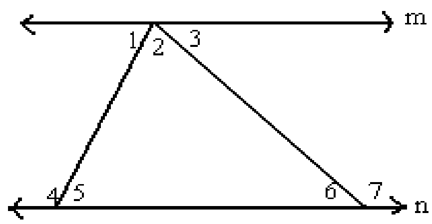
e) Seçeneklerden hiçbiri her ikizkenar üçgen için doğru değildir.

16.) Üçgen, üç kenarı ve üç açısı olan bir şekildir. Bir ABC üçgeninde, bütün kenarlar eşit uzunluktadır. [AB]=[BC]=[AC]

Yargı: Üçgendeki bütün açıların ölçüleri de eşittir. s(A)=s(B)=s(C)

Doğru /   Yanlış / Başka bir cevap. Cevabınızı açıklayınız.

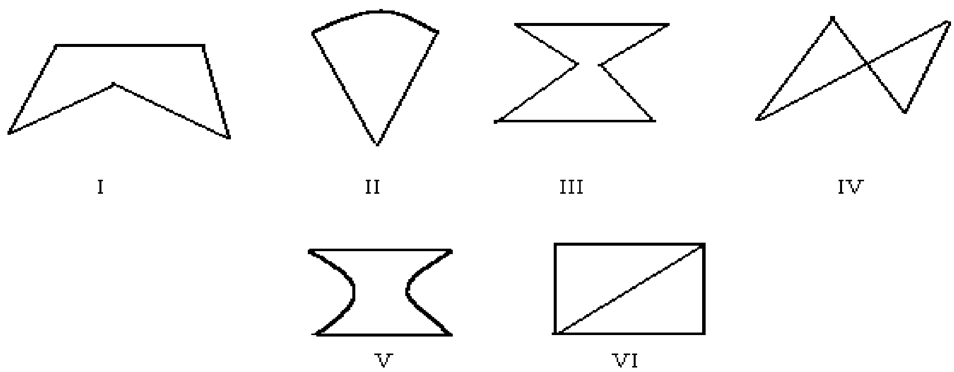
17.) m ve n doğruları paraleldir.(m//n)
Aşağıdaki ifadelerden hangisi veya hangileri doğrudur?
Neden? (<1: s(1))



a) <4=<2+<6 b) <3=<2+<5 c) <1+<2+<6=180
d) <4+<1=180 e)<7=<2 f)<2+<6=180

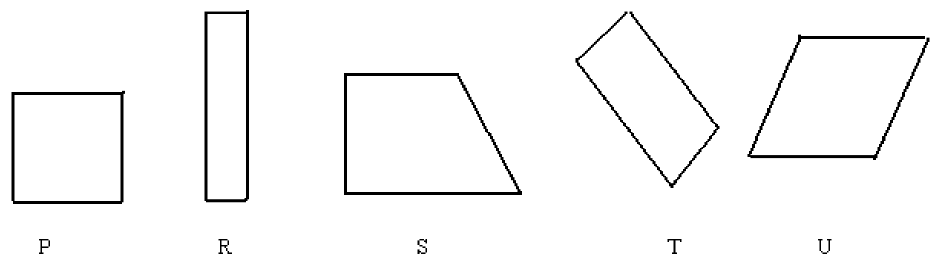
18.) a) Aşağıdaki şeklillerden hangisi yada hangileri çokgendir?

b) Neden?



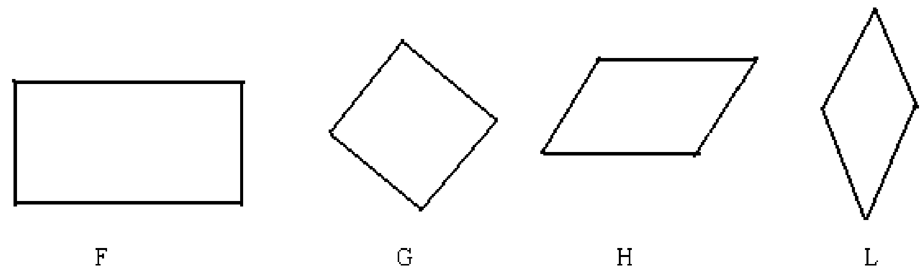
19.) a) Aşağıdaki şeklillerden hangisi yada hangileri dikdörtgendir?

b) Neden?



20.) a) Aşağıdaki şekillerden hangisi yada hangileri karedir?

b) Neden?



21.) Aşağıdakilerden hangisi doğrudur?

a) Dikdörtgenin tüm özellikleri tüm kareler için de geçerlidir.

b) Karenin tüm özellikleri tüm dikdörtgenler için de geçerlidir.

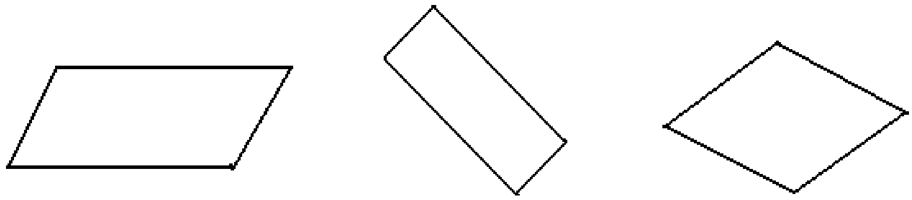
c) Dikdörtgenin tüm özellikleri tüm paralelkenarlar için de geçerlidir.

d) Karenin tüm özellikleri tüm paralelkenarlar için de geçerlidir.

e) Yukarıdaki seçeneklerden hiçbiri doğru değildir.

22.) a) Aşağıdaki şekillerden hangisi yada hangileri paralelkenardır?

b) Neden?



K L M

APPENDIX B

COMPUTER ATTITUDE SCALE (CAS)

AD, SOYAD:

SINIF: **NO:** **YAŞ:** **CİNSİYET:**

BİLGİSAYARLI EĞİTİME KARŞI TUTUM ÖLÇEĞİ

Genel Açıklama: Bu bir bilgi testi değildir ve bu nedenle hiçbir sorunun "doğru" cevabı yoktur. Aşağıda yer alan sorularla Geometer-Sketchpad ile yapmış olduğunuz geometri dersleriniz hakkındaki fikirlerinizi almak istiyoruz. Her cümle için kendinize en uygun seçeneği işaretleyiniz.

1) Geometriyi bilgisayarda öğrenirken kendimi yalnız ve insanlardan uzak hissettim.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

2) Bilgisayarda çalışırken, kendimi kendimi öğrenmeye çalışmaktan çok sadece konuyu bitirmeye çalışırken buldum.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

3) Geometriyi bilgisayarda öğrenmem sonucunda, konu ile ilgili daha çok bilgi edindim.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

4) Konuyu anlamaktan çok bilgisayarı kullanmakla ilgilendim.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

5) Bilgisayarlı eğitimle çalışırken özel bir öğretmenle çalışıyormuş gibi hissettim.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

6)Geometri bilgisayar programının kullanımı nedeniyle, konuya konsantre olmakta güçlük çektim.

A) Her zaman B) Çoğu zaman C) Bazen D) Çok nadir E) Hiç

7) Bilgisayarlı eğitim, kendimi gergin hissetmeme neden oldu.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

8) Bilgisayarlı eğitim öğrencinin zamanını boşa harcıyor.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

9) Bilgisayar destekli eğitimle almış olduğum geometri konularına karşı duygularım............

A) Çok olumluydu B)Olumluydu C)Tarafsızdı D)Olumsuzdu

E) Çok Olumsuzdu

10) Bilgisayarlı eğitim daha hızlı öğrenmemi sağladı.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

11) Bilgisayarlı eğitimden hoşlandım.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

12) İlginç olabilecek konular bile, bilgisayarlı eğitimle sunulduğunda sıkıcı olabilir.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

13) Gösterdiğim çabayı göz önüne alırsak, bilgisayarlı eğitimden öğrendiklerim beni tatmin etti.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

14) Ne kadar çok öğrendiğimize bakılırsa, bilgisayarlı eğitimin geleneksel eğitimden daha üstün olduğunu söyleyebilirim.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

15) Bilgisayarlı eğitimle öğrendiğim konuyu göz önüne alırsak, bilgisayarlı eğitimi geleneksel eğitime tercih ederim.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

16) Bilgisayar üzerinde verilen materyaller derse karşı olan ilgiyi artırdı.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

17) Genel olarak bilgisayar labratuarında yapılan çalışmalar, dersin değerli kısımlarından biriydi.

A) Kesinlikle hayır B)Hayır C)Belirsiz D)Evet E)Kesinlikle evet

18) Bilgisayarlı eğitimde verimli olarak bir oturuşta ne kadar çalışabileceğinizi düşünüyorsunuz?

A) 30 dakikadan az B)30-60 dak. C)60-90 dak.D)90-120dak.E)2-3 saat

Aşağıda yer alan soruları Geometer-Sketchpad ile yapmış olduğunuz geometri dersleri ile ilgili olarak cevaplandırınız. Lütfen nedenleri ile yazınız.

1) Bilgisayarlı eğitim geometride sizlere ne şekilde faydalı oldu?

2) Geometri dersinin bilgisayar destekli kısmına ne gibi değişiklikler önerebilirsiniz?

3) Geometri dersine bütün olarak ne gibi değişiklikler önerebilirsiniz?

4) Geometri de sizin çalışmalarınızı etkileyen en önemli faktörler nelerdir?

APPENDIX C

TEACHING MATERIALS IN THE EXPERIMENTAL GROUP

(SKETCHSHEETS)

Ders: Geometri 1

Konu: Bir Düzlemde İki Doğrunun Birbirine Göre Durumları

<u>Sketchpad Aktivite :</u>

1) Sketchsheet' de 2 doğru çiziniz. Bu doğrular birbirlerine göre hangi durumda bulunabilirler.(Doğruları uç noktalarından tutarak hareket ettirebilirsiniz.)Bulduğunuz durumları yazınız.

Ders: Geometri 2

Konu: Bir Düzlemde İki Doğrunun Birbirine Göre Durumları

Eş Açılar

2) Aktivite 1 e göre;

a) Kesişen doğruların kesişim kümesi nedir?

b) En çok kaç noktada kesişirler?

c) Çakışık doğruların kesişim kümesi nedir?

d) En çok kaç noktada kesişirler?

e) Paralel doğruların kesişim kümesi nedir?

f) En çok kaç noktada kesişirler?

Sketchpad Aktivite:

➢ Ölçüleri birbirine eşit olan açılara eş açılar denir.

1) Sketchsheet'de eş açılar yaratınız ve bu açıların derecelerini ölçünüz.

Ders: Geometri 3
Konu: Komşu Açılar
Tümler Açılar

- Köşeleri ve birer kenarları ortak. diğer kenarları ise ortak kenarın farklı tarafında bulunan açılara *Komşu Açılar* denir.

Sketchpad Aktivite:

1) Yukarıda verilen komşu açı tanımına göre. Sketchsheet'de farklı komşu açılar yaratınız.
2) Eş komşu açılar yaratınız. (Açıların derecelerini ölçebilirsiniz)

3) Köşeleri ortak fakat komşu açı olmayan açılar yaratınız.

- Ölçüleri toplamı 90º olan açılara *Tümler Açılar* denir.

Sketchpad Aktivite:
1) Yukarıda verilen tanıma göre tümler açılar yaratınız. (Yarattığınız açıların ölçülerini gösteriniz)

2) Karşınıza gelen yeşil ve kırmızı ışınlara ilaveten ışınlar çizerek komşu tümler açılar ve eş komşu tümler açılar yaratınız. Bu açıların ölçülerini yazınız.

3) İki tümler açıdan biri diğerinin 4 katıdır. Bu tümler açıların ölçülerini Aktivite 2 deki açılar üzerinde gösteriniz.

Ders: Geometri 4

Konu: Bütünler Açılar

Doğrusal Noktalar

➢ Ölçüleri toplamı 180° olan iki açıya *Bütünler açılar* denir.

<u>Sketchpad Aktivite:</u>

1) Yukarıda verilen tanıma göre bütünler açılar yaratınız. (Yarattığınız açıların ölçülerini gösteriniz)

2) Karşınıza gelen yeşil ve kırmızı ışınlara ilaveten ışınlar çizerek komşu bütünler açılar ve eş komşu bütünler açılar yaratınız. Bu açıların ölçülerini yazınız. .

➢ Aynı doğru üzerinde yer alan noktalara *Doğrusal Noktalar* denir.

<u>Sketchpad Aktivite:</u>

1)A, D, E ve G noktaları doğrusaldır. Gösteriniz.

Ders: Geometri 5
Konu: Ters Açılar

- Köşeleri ortak ve kenarları (ışınları) birbirine ters yönde olan açılara *Ters Açılar* denir.

<u>Sketchpad Aktivite:</u>

1) Yukarıda verilen ters açı tanımına göre Sketchsheet' de ters açılar yaratınız.
Yarattığınız ters açıların ölçüleri hakkında ne söyleyebilirsiniz?

2) Ters açıları oluşturan doğruların düzlemde birbirlerine göre durumları nedir?

3) Sketchsheet'de ters açıları oluşturun.
Bu şekil üzerinde başka ne tür açılar görebiliyorsunuz?

Ders: Geometri 6
Konu: Paralel İki Doğrunun Bir Kesenle Yaptığı Açılar

Sketchpad Aktivite

1) Sketchsheet'de birbirine paralel iki doğru ve bu iki paralel doğruları kesen bir doğru çiziniz. Çizdiğiniz doğruların paralel olduğunu nasıl anlarsınız?

a) Oluşan şekildeki açıları gösterip derecelerini ölçünüz

b) Derecelerini ölçtüğünüz açılar arasında nasıl bir ilişki vardır?

2) 1. Aktiviteyi tamamladıktan sonra, paralel doğruların paralelliğini bozunuz (Doğruların uç noktalarında çekerek hareket ettiriniz).

3) Paralellik bozulurken açıların ölçülerini inceleyiniz. Dereceler hakkında ne söylersiniz?

4) 1. ve 2. Aktivite sonunda. nasıl bir yargıya vardınız?

Ders: Geometri 7

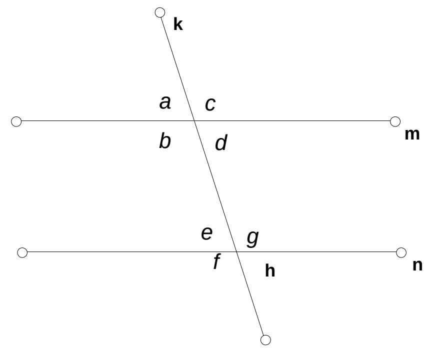
Konu: Yöndeş Açılar

İçters Açılar

- *Yöndeş Açılar*: Birer kenarları aynı doğru üzerinde, diğer kenarları da paralel ya da aynı yönlü olan doğrular olan açılardır.

Sketchpad Aktivite:

1) Tanıma göre hangi açılar yöndeştir?



---- ile ----- yöndeş açılardır ve ----=-----

---- ile ----- yöndeş açılardır ve ----=-----

---- ile ----- yöndeş açılardır ve ----=-----

---- ile ----- yöndeş açılardır ve ----=-----

2) Bir önceki aktiviteye göre yöndeş açıların arasında nasıl bir ilişki buldunuz?

e+ b= ------ derecedir. } Bu açılara *Karşı Ardışık Açılar* denir

g+d=--------derecedir. }

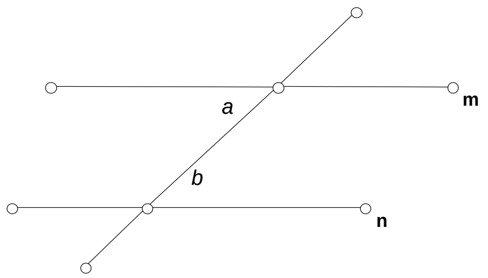
Ders: Geometri 8
Konu: İçters Açılar
Dışters Açılar

- *İçters Açılar*: Paralel doğruların iç bölgesinde yer ala, birer kenarları ortak ve aynı doğru üzerinde, diğer kenarları birbirine paralel ve ters yönlü açılardır.

Sketchpad Aktivite:

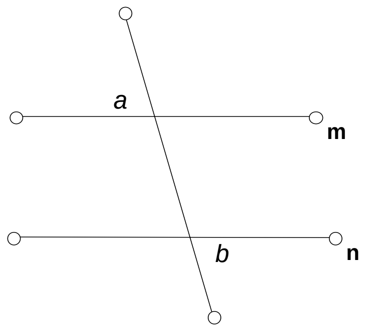
1)Tanıma göre başka hangi açılar içterstir? Gösteriniz.

Sizde ekarnınızda içters açılar yaratınız?



- Dışters Açılar: Paralel doruların dış bölgesinde kalan, kenarları birbirine paralel ve yönleri ters olan açılardır.

2) Tanıma göre hangi açılar dışterstir?



Aktivite 2 de bulduğunuz dışters açıların ölçüleri arasında nasıl bir ilişki buldunuz

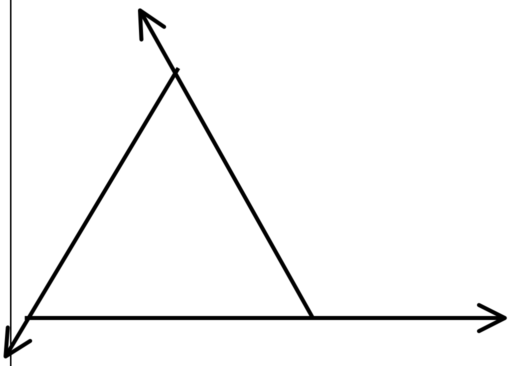
Ders: Geometri 9

Konu: Üçgen

Sketchpad Aktivite:

Ders: Geometri 10

Ders: Geometri 11

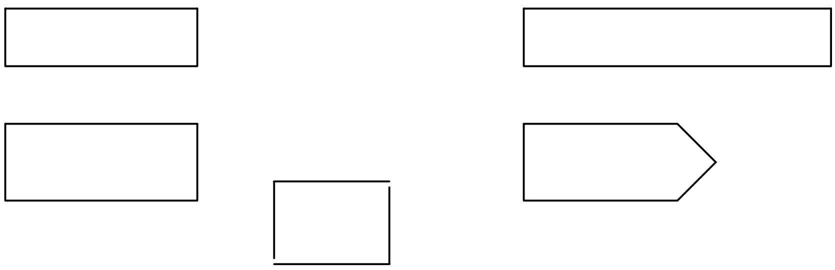


Ders: Geometri 12

Ders: Geometri 14

Ders: Geometri 15

Ders: Geomteri 18



APPENDIX D

Frequency and Percentage of EG and CG students' Correct Answers in Pre, Post and Delay GPT

	Experimental Group			Control Group		
	Pre-Test	Post-test	Delay -Test	Pre-Test	Post-Test	Delay -Test
Q1a	29 (93.5%)	31 (100%)	30 (96.8%)	29 (90.6%)	29 (90.6%)	27(84.4%)
Q1b	30 (96.8%)	31 (100%)	30 (96.8%)	31 (96.9%)	32 (100%)	29 (90.6%)
Q1c	31 (100%)	31 (100%)	30 (96.8%)	32 (100%)	32 (100%)	29 (90.6%)
Q1d	30 (96.8%)	31 (100%)	31 (100%)	27 (84.4%)	31(96.9%)	28 (87.5%)
Q1e	31 (100%)	31 (100%)	30 (96.8%)	31 (96.9%)	29 (90.6%)	28 (87.5%)
Q1expl.	11 (35.5%)	24 (77.4%)	23 (74.2%)	16 (50%)	20 (62.5%)	10 (31.3%)
Q2a (parallel lines)	11 (35.5%)	24 (77.4%)	17 (54.8%)	3 (9.4%)	14 (43.8%)	13 (40.6%)
Q2b (coinciding lines)	10 (32.3%)	20 (64.5%)	17 (54.8%)	2 (6.3%)	3 (9.4%)	2 (6.3%)
Q2c(intersecting lines)	4 (12.9%)	11 (35.5%)	15 (48.4%)	2 (6.3%)	11 (34.4%)	11 (34.4%)
Q3	5 (16.1%)	5 (48.4%)	12 (38.7%)	9 (28.1%)	7 (21.9%)	8 (25.0%)
Q4a	23 (74.2%)	31 (100%)	30 (96.8%)	30 (93.8%)	30 (93.8%)	27 (84.4%)
Q4b	6 (19.4%)	18 (58.1%)	19 (61.3%)	4 (12.5%)	10 (31.3%)	14 (43.8%)
Q4c	24 (77.4%)	31 (100%)	30 (96.8%)	30 (93.8%)	31 (96.9%)	27 (84.4%)
Q4d	13 (41.9%)	17 (54.8%)	24 (77.4%)	8 (25%)	13 (40.6%)	14 (43.8%)
Q4e	23 (74.2%)	31 (100%)	30 (96.8%)	29 (90.6%)	27 (84.4%)	26 (81.3%)
Q4f	11 (35.5%)	15 (48.4%)	20 (64.5%)	7 (21.9%)	11 (34.4%)	11(34.4%)
Q5a	22 (71%)	28 (90.3%)	29 (93.5%)	28 (87.5%)	32 (100%)	26 (81.3%)
Q5b	30 (96.8%)	29 (93.5%)	29 (93.5%)	27 (84.4%)	31 (96.9%)	27 (84.4%)
Q5c	18 (58.1%)	28 (90.3%)	30 (96.8%)	28 (87.5%)	32 (100%)	26 (81.3%)

Not: "expl." means explanation items

	Experimental Group				Control Group		
	Pre-Test	Post-Test	Delay-Test		Pre-Test	Post-Test	Delay- Test
Q5d	11 (35.5%)	9 (29%)	17 (54.8%)		3 (9.4%)	10 (31.3%)	22 (68.8%)
Q6a	22 (71%)	29 (93.5%)	30 (96.8%)		24 (75%)	26 (81.3%)	23 (71.9%)
Q6b	19 (61.3%)	28 (90.3%)	26 (83.9%)		19 (59.4%)	25 (78.1%)	21 (65.6%)
Q6c	23 (74.2%)	28 (90.3%)	29 (93.5%)		24 (75%)	24 (75.0%)	20 (62.5)
Q6d	20 (64.5%)	26 (83.9%)	25 (80.6%)		20 (62.5%)	2 (78.1%)	18 (56.3%)
Q6e	14 (45.2%)	22 (71%)	22 (71%)		14 43.8%)	21 (65.6%)	17 (53.1%)
Q6expl.	1 (3.2%)	18 (58.1%)	17 (54.8%)		7 (21.9%)	15 (46.9%)	9 (28.1%)
Q7	25 (80.6%)	31 (100%)	22 (71%)		23 (71.9%)	27 (84.4%)	24 (75.0%)
Q8a	7 (22.6%)	11 (35.5%)	5 (16.1%)		1 (3.1%)	5 (15.6%)	9 (28.1%)
Q8b	8 (25.8%)	18 (58.1%)	10 (32.3%)		1 (3.1%)	16 (50.0%)	5 (15.6%)
Q9	3 (9.7%)	7 (22.6%)	10 (32.3%)		4 (12.5%)	6 (18.8%)	9 (28.1%)
Q10	11 (35.5%)	15 (48.4%)	20 (64.5%)		7 (21.9%)	18(56.3%)	23 (71.9%)
Q11	5 (16.1%)	16 (51.6%)	9 (29%)		5 (15.6%)	3 (9.4%)	2 (6.3%)
Q12a	29 (93.5%)	30 (96.8%)	31 (100%)		27 (84.4%)	27 (84.4%)	27 (84.4%)
Q12b	30 (96.8%)	31 (100%)	30 (96.8%)		29 (90.6%)	27 (84.4%)	28 (87.5%)
Q12c	31 (100%)	30 (96.8%	30 (96.8%)		30 (93.8%)	32(100.0%)	29 (90.6%)
Q12d	25 (80.6%)	28 (90.3%)	17 (54.8%)		19 (59.4%)	19 (59.4%)	10 (31.3%)
Q12expl.	7 (22.6%)	29 (93.5%)	21 (67.7%)		23 (71.9%)	26 (81.3%)	19 (59.4%)
Q13a	22 (71%)	26 (83.9%)	20 (64.5%)		29 (90.6%)	26 (81.3%)	20 (62.5%)
Q13b	19 (61.3%)	24 (75%)	27 (87.1%)		27 (84.4%)	26 (81.3%)	25 (78.1%)

	Experimental Group				Control Group		
	Pre-Test	Post-Test	Delay-Test		Pre-Test	Post-Test	Delay-Test
Q13c	18 (58.1%)	23 (74.2 %)	17 (54.8%)		26 (81.3%)	25 (78. %1)	21 (65.6%)
Q14a (I-II scalene)	10 (32.3%)	23 (74.2%)	20 (64.5%)		9 (28.1%)	15 (46.9%)	8 (25.0%)
Q14b (I-III equilateral)	13 (41.9%)	19 (61.3%)	20 (64.5%)		11 (34.4%)	12 (37.5%)	6 (18.8%)
Q14c (II-III scalene)	8 (25.8%)	17 (54.8%)	15 (48.4%)		11 (34.4%)	14 (43.8%)	6 (18.8%)
Q14d (IV-V isosceles)	7 (22.6%)	19 (61.3%)	13 (41.9%)		11 (34.4%)	11 (34.4%)	6 (18.8%)
Q14e (IV-VII acute)	3 (9.7%)	18 (58.1%)	12 (38.7%)		10 (31.3%)	13 (40.6%)	16 (50.0%)
Q14f (V-VI isosceles)	9 (29%)	16 (51.6%)	19 (61.3%)		8 (25%)	11 (34.4%)	7 (21.9%)
Q14g (III-VI obtuse)	5 (16.1%)	6 (19.4%)	5 (16.1%)		2 (6.3%)	3 (9.4%)	2 (6.3%)
Q14h (II-V right)	3 (9.7%)	7 (22.6%)	10 (32.3%)		1 (3.1%)	5 (15.6%)	7 (21.9%)
Q14i (IV-VII acute)	1 (3.2%)	1 (3.2%)	3 (9.7%)		1 (3.1%)	0 (0%)	2 (6.3%)
Q14j (I-IV acute)	6 (19.4%)	3 (9.7%)	3 (9.7%)		1 (3.1%)	0 (0%)	2 (6.3%)
Q15	20 (64.5%)	22 (71%)	19 (61.3%)		14 (43.8%)	19 (59.4%)	13 (40.6%)
Q16a	20 (64.5%)	27 (87.1%)	26 (83.9%)		14 (43.8%)	18 (56.3%)	26 (81.3%)
Q16expl.	7 (22.6%)	23 (74.2%)	19 (61.3%)		3 (9.4%)	8 (25.0%)	14 (43.8%)
Q17a	6 (19.4%)	25 (80.6%)	22 (71%)		23 (71.9%)	23 (71.9%)	16 (50.0%)
Q17b	16 51.6%)	23 (74.2%)	19 (61.3%)		21 (65.6%)	28 (87.5%)	22 (68.8%)
Q17c	13 (41.9%)	14 (45.2%)	10 (32.3%)		13 (40.6%)	6 (18.8%)	12 (37.5%)
Q17d	11 (35.5%)	17 (54.8%)	14 (45.2%)		5 (15.6%)	13 (40.6%)	10 (31.3%)
Q17e	15 (48.4%)	19 (61.3%)	25 (80.6%)		20 (62.5%)	19 (59.4%)	18 (56.3%)
Q17f	21 (67.7%)	23 (74.2%)	26 (83.9%)		26 (81.3%)	29 (90.6%)	21 (65.6%)

	Experimental Group				Control Group		
	Pre-Test	**Post-Test**	**Delay- Test**		**Pre-Test**	**Post-Test**	**Delay-Test**
Q18a	15 (48.4%)	27 (87.1%)	13 (41.9%)		10 (31.3%)	14 (43.8%	15 (46.9%)
Q18b	26 (83.9%)	31 (100%)	31 (100%)		30 (93.8%)	30 (93.8%)	28 (87.5%)
Q18c	18 (58.1%)	20 (64.5%)	13 (41.9%)		12 (37.5%)	16 (50.0%)	18 (56.3%)
Q18d	14 (45.2%)	20 (64.5%)	15 (48.4%)		6 (18.8%)	6 (18.8%)	12 (37.5%)
Q18e	25 (80.6%)	31 (100%)	30 (96.8%)		29 (90.6%)	26 (81.3%)	26 (81.3%)
Q18f	16 (51.6%)	13 (41.9%)	16 (51.6%)		10 (31.3%)	10 (31.3%)	13 (40.6%)
Q18expl.	2 (6.5%)	13 (41.9%)	4 (12.9%)		5 (15.6%)	5 (15.6%)	4 (12.5%)
Q19a	1 (3.2%)	20 (64.5%)	12 (38.7%)		2 (6.3%)	4 (12.5%)	3 (9.4%)
Q19b	30 (96.8%)	30 (96. 8%)	30 (96.8%)		31 (96.9%)	28 (87.5%)	29 (90.6%)
Q19c	30 (96.8%)	31 (100%)	30 (96.8%)		31 (96.9%)	31 (96.9%)	27 (84.4%)
Q19d	18 (58.1%)	27 (87.1%)	22 (71%)		17 (53.1%)	12 (37.5%)	14 (43.8%)
Q19e	28 (90.3%)	29 (93.5%)	26 (83.9%)		26 (81.3%)	28 (87.5%)	25 (78.1%)
Q19expl.	12 (38.7%	27 (87.1%)	22 (71%)		15 (46.9%)	18 (56.3%)	14 (43.8%)
Q20a	30 (69.8%)	29 (93.5%)	28 (90.3%)		31 (96.9%)	30 (93.8%)	30 (93.8%)
Q20b	29 (93.5%)	26 (83.9%)	23 (74.2%)		30 (93.8%)	28 (87.5%)	30 (93.8%)
Q20c	31 (100%)	31 (100%)	30 (96.8%)		31 (96.9%)	30 (93.8%)	29 (90.6%)
Q20d	29 (93.5%)	30 (96.8%)	23 (74.2%)		20 (62.5%)	26 (81.3%)	28 (87.5%)
Q20rexpl.	24 (77.4%)	28 (90.3%)	29 (93.5%)		30 (93.8%)	28 (87.5%)	27 (84.4%)
Q21	2 (6.5%)	8 (25.8%)	4 (12.9%)		1 (3.1%)	2 (6.3%)	1 (3.1%)

	Experimental Group				Control Group		
	Pre-Test	Post--Test	Delay- Test		Pre-Test	Post--Test	Delay- Test
Q22a	27 (87.1%)	31 (100%)	31 (100%)		31 (96.9%)	31 (96.9%)	29 (90.6%)
Q22b	4 (12.9%)	24 (77.4%)	19 (61.3%)		8 (25%)	18 (56.3%)	10 (31.3%)
Q22c	12 (38.7%)	27 (87.1%)	25 (80.6%)		15 (46.9%)	19 (59.4%)	17 (53.1%)
Q22expl.	1 (3.2%)	26 (83.9%)	20 (64.5%)		14 (43.8%)	17 (53.1%)	15 (46.9%)