Thesis Submitted for the MSC in Mathematics and Science Education

Traditional teaching about Angles compared to an Active Learning Approach that focuses on students’ skills in seeing, measuring and reasoning, including the use of Dynamic Geometry Software: Differences in achievement

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Abstract

An active learning approach is a teaching method that aims to trigger students active involvement in their learning activities, and Dynamic Geometry Software (DGS) is a kind of software program which allows a user to create and manipulate any geometrical figure. This research is about combining those things in a designed teaching method. An active learning approach using DGS was implemented at a junior high school in Indonesia. There were two classes involved in this experiment, one as the experimental class and the other one as the control class. To compare students’ achievements in learning one topic of geometry, the angle concept, the researcher taught his design lesson sequence to the experimental class. Meanwhile the collaborative teacher taught using the traditional teaching method (without using DGS) to the control class.

The pretest results show that both classes were not significantly different in their ability to know the concept of angle before the intervention began. But after the intervention was done, the posttest results show that they were significantly different in their achievement of understanding the concept of angle. By using ANCOVA, the data analysis shows that the intervention significantly affected students of the experimental class in understanding the concept of angle.
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1. Introduction

In the researcher’s opinion, teaching mathematics is a very challenging thing to do because mathematics teachers, students, and mathematics subjects should be running together in harmony, which means mathematics teachers teach using an appropriate teaching method for students, students are able to engage in their learning activities, and the mathematics subjects taught are suitable to students’ level of thinking. One of possible problems in teaching and learning mathematics is that mathematics teachers, in their opinion, think that their regular teaching method is appropriate to students without trying to evaluate whether students are really satisfied with their teaching method. On the other hand, students do not think that their mathematics teachers use an appropriate teaching method for teaching them. Meanwhile mathematics is still considered as a difficult subject to learn by some students, however they must take it, because mathematics is one of the compulsory subjects that students must accomplish in their study, at least from elementary school to senior high school levels. That is why some students feel tortured every time they meet a mathematics class in their study. Actually there are some reasons for this condition, such as students do not see the relevance of mathematics to their life, which makes it hard for them to understand it; mathematics teachers do not provide suitable and appropriate teaching methods so that students are not engaging in learning mathematics; there is not enough teaching-learning media to help students become more enthusiastic and motivated to learn mathematics.

I think that to overcome this condition, mathematics teachers should be more innovative in their teaching methods. Mathematics teachers also should consider the use of ICT in their teaching, because use of ICT in education can help students understand and help teachers explain mathematics subjects more effectively. There exists a lot of research investigating the use of ICT in education, and it shows that students become more independent in doing their learning activities when they engage in learning through ICT tools. An example of the use of ICT in education is the use of mathematics software to teach students. Mathematics software is a
kind of application program that has the special function to help its user understand about the mathematics topics they learn. There are many kinds of mathematics software, such as Cinderela, Geogebra, Mathematica, etc. Mathematics software nowadays is easy enough to use and to understand, most are really user friendly, so that users do not need special computer skills to use them. Some mathematics software is free which means that users can use the software without needing a license.

One of the free mathematics software programs is Geogebra, a kind of software called dynamic geometry software (DGS). The definition of dynamic geometry is: "the theory of construction-like descriptions of function-like objects under parameter changes" (Kortenkamp, 1999). Meanwhile dynamic geometry software is a computer program by which a user can construct or create any plane geometrical shape, then can manipulate it as well. Therefore dynamic geometry software is really helpful for teaching and learning geometry, because in it there are a lot of tools that can be used to visualize and to construct geometrical shapes in simple ways. By learning geometry through dynamic geometry software, the researcher hopes that students will be more excited about learning geometry, and it will make them engage more in their learning activities.

Teaching and learning geometry traditionally only uses common tools, such as a blackboard, a protractor, a ruler, and a compass. I do not mean to imply that a traditional way of teaching geometry is not appropriate to students. However, to use those tools is sometimes difficult for students and it takes time to create or construct geometrical shapes. Therefore some students will lose the time needed to understand geometry, because the drawing of geometrical figures is so time consuming, and this condition makes students think that learning geometry is not fun and it is difficult as well. It shows that students’ achievement and opinion are affected by the tools used for teaching.

This condition triggered me to do a research study in which I conducted an intervention of teaching geometry through dynamic geometry software, Geogebra. I wanted to compare
students’ achievement in learning geometry in a class taught in the traditional way and a class taught according to the designed intervention.
2. Theoretical Framework

Geometry is a branch of mathematics studying shapes and configurations. In learning geometry there are some skills that students should acquire such as intuition, measuring, and reasoning skills. Students should have all these abilities after they learned geometry well. One of the geometry topics is the angle concept, which is foundational for learning geometry. There are some stages in which children understand the concepts of angle which are from concrete to abstract (Mitchelmore and White, 2004). Geometry topics are sometimes related to visualization of concepts and definitions of geometry objects. For example, a line can be created by connecting two points. To visualize this concept, a picture of a line should be drawn to make the concepts more real to students. Many kinds of tools can be used to visualize geometry concepts. One of the tools is dynamic geometry software. By using such software, students will easily be able to draw and manipulate a geometrical picture. In teaching and learning activities, especially in teaching mathematics, mathematics teachers should not be the center of the class, and students should be more active and independent in their learning activities. In the researcher’s opinion, an active learning approach which combines with the use of DGS will help students learn mathematics much better and also will make them active and critical in learning activities. This is the reason why I was interested in doing a research study about it.

2.1 Skills in learning geometry

Many educators and researchers in mathematics argue that intuition plays a crucial role in geometry, and that an intuition process in geometry comes into one’s mind after seeing shapes of geometrical things. Actually, it is difficult to define what exactly the definition of intuition in geometry is, but generally it is a skill to ‘see’ geometrical figures even if they are not drawn on paper. Creating and manipulating such figures in the mind to solve problems in geometry can be regarded as an intuition skill (Fujita, Jones, and Yamamoto, 2004 b). This means that intuition relates to what students see and then think about. Treutlein (1911; in
Fujita, Jones, and Yamamoto, 2004b) considered intuition as an essential skill in geometry as well as in everyday life, and argued that training students’ ‘imagination’ through geometry was very important. An interesting example of Treutlein’s tasks for students is when he asked students to make new figures in their mind by manipulating two (given) triangles. (see figure 2.1)

![Figure 2.1 Formation of new figures](image)

Students were asked to make as many combination figures as they could by mentally manipulating the first two triangles. The more often students use their ‘imagination’ in geometry, the higher the possibility that they improve their intuition skill in it. To be a successful problem solver in geometry, a student must practice and exercise a skill, which is called ‘geometrical intuition’, in creating and manipulating geometrical figures in the mind, perceiving geometrical properties, relating images to concepts and theorems in geometry, and deciding where and how to start showing a given problem in geometry (Fujita, Jones, and Yamamoto, 2004 a).

Measuring in geometry is one of the important skills in order to determine the size of an angle, length, area, or volume of geometrical things. Measuring in geometry is mostly related to using tools such as a ruler, a compass, a protractor, etc. By using such tools students can measure real geometrical things, and they can investigate whether their intuition about geometrical objects is accurate or not. For example, when students are asked to investigate whether two given triangles are congruent or not, students can use their intuition to answer the question. However, to make sure whether the students’
intuitive answer is correct or not, they need to use a ruler and a protractor to measure all properties of each triangle.

Reasoning in geometry relates to abilities to give logical explanations, argumentations, verifications, or proofs to arrive at convincing solutions to geometrical problems. Intuition and measuring skills need to be supported by reasoning skills. This means that reasoning plays a justification role for what intuition and measurement give as solutions to geometry problems. Actually, good reasoning will make a solution of a geometry problem more mathematical and more elegant. Through reasoning skills students can enhance their understanding about geometry and find it possible to make other theories from what they have learned and understood.

Geometry deals with mental entities (geometrical figures) which possess conceptual and figural characters (Fischbein, 1993). Concepts and images are considered two basically distinct categories of mental entities. Pieron (1957; in Fischbein, 1993) defines a concept as a symbolic representation (almost always verbal) used in the process of abstract thinking and possessing a general significance corresponding to an ensemble of concrete representations with regard to what they have in common. Meanwhile, an image is a sensory representation of an object or phenomenon. For example, an angle is an abstract ideal concept, but it also possesses figural properties. Actually, the absolute perfection of a geometrical angle cannot be found in reality, even though we can find many different contexts of angle.

2.2 How children think and learn about concepts of angle

Mathematical objects may best be described as abstract-apart, since mathematics is essentially a self-contained system, but on the other hand, fundamental mathematical ideas are closely related to the real world and their learning involves empirical concepts (Mitchelmore and White, 2004). In everyday life we can see situations around us as many kinds of angle contexts, such as the intersection between two streets, inclination or slope,
corners of a table, an end point of a pen, etc. That is why the angle concept is special because it can appear in so many different contexts. Henderson (in Lehrer, 2003) suggests three conceptions of angle, which are (1) angle as movement, (2) angle as a geometric shape, and (3) angle as a measure. The angle concept as movement can be contextual in rotation or sweep, the angle concept as a geometric shape can be contextual in a delineation of space by two intersecting lines, and the angle concept as a measure can be contextual in a perspective that coordinates the first two.

Children find it difficult to learn the angle concept because of the multifaceted nature of angle (Mitchelmore & White, 2000), and to acquire a general concept of angle, students need to see the similarities between the various angle contexts and identify their essential common features (Mitchelmore & White, 2004). In understanding about concepts of angle, children pass through some developmental stages, during which “children progressively recognize deeper and deeper similarities between their physical angle experiences and classify them firstly into specific situations, then into more general contexts, and finally into abstract domains”, and during which, from the classification at each stage of development, an angle concept is abstracted (Mitchlemore & White, 2000).

2.3 Dynamic Geometry Software (DGS)

Teaching mathematics in a regular or traditional way without using ICT does not mean that the method is not appropriate for students. However, teaching mathematics through using ICT nowadays has become a familiar trend in many countries. Using ICT in education is a method to help teachers and students to interact in a better way in teaching-learning activities (Jhurree, 2005). One example of the use of ICT in education is using dynamic geometry software to teach mathematics to students, especially geometry. Dynamic geometry software is a certain type of software which is predominantly used for the construction and analysis of tasks and problems in elementary geometry (Straber, Bielefeld, and Lulea, 2002). With this software a user can construct, create, and manipulate all kinds of geometrical shapes. Using DGS in learning activities will be helpful to students, because it
provides them with access to the world of geometrical theorems, which is mediated by features of the software environment, certainly in the vital early and intermediate stages of using the software (Jones, 2000).

There are many kinds of DGS such as Cabri, Cinderela, Geogebra, etc. Some are free software, which means users do not need a license to use the software; one of these is Geogebra. This software can be downloaded free of charge on the official site of Geogebra which is http://www.geogebra.org/cms/. Geogebra provides many tools in which users can interactively create and manipulate geometrical shapes to find geometrical theories. This software does not require special skills in computer programming to use it. To learn about angle concepts, Geogebra also provides many tools to students to enable them to understand angle concepts. Students can do many experiments by creating, drawing, constructing, and manipulating any angles they desire. Since geometry always relates to shapes and configurations, visualization is very important in helping students to learn geometry. By providing visualizations of geometrical shapes children will easily learn to recognize them, and after this they can use their intuition, measuring, and reasoning skills to respond to questions related to the shapes. Since Geogebra provides such good tools for visualization of geometrical objects, I chose Geogebra as the DGS to use in teaching geometry in my intervention.

2.4 Active Learning
In the traditional teaching method, teachers are always being the center of teaching and learning activities, which means that teachers are active, and students are passive in the class. In this method teachers give lectures to students and after that teachers give some examples of what they just taught. Meanwhile, students are only listening to what their teachers explain, and doing some exercises after they get some examples of the exercises. In my opinion, such a teaching method makes students become dependent on their teachers, so that they will not be able to learn how to be critical, innovative, and creative in their learning activities. Students will only get superficial understanding of what they
learned by such a rote method. In my opinion, to overcome this problem, mathematics teachers should modify or even change their traditional teaching method to an active learning approach.

“Active learning differs from “learning from examples” in that the learning algorithm assumes at least some control over what part of the input domain it receives information about” (Atlas, L, Chon, D., & Ladner, R. 1990). This means that a teaching method which consists of only giving students some examples and then asking them to learn from those and after that asking students to solve some similar questions by themselves is not an active learning technique. In an active learning approach, teachers should be more aware of their students’ actions in learning activities, and teachers should make their students more active, more engaged, and more critical in class activities. To prepare for active learning activities, teachers should design a lesson plan in which students must read, write, discuss, or be engaged in solving problems (Bonwell, C. Charles, 1991). Therefore, in such teaching methods, teachers are not the center of the class, but students are the centre of the learning activities. “Most important, to be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. Within this context, it is proposed that strategies promoting active learning be defined as instructional activities involving students in doing and thinking about what they are doing” (Bonwell, C. Charles, 1991). Bonwell suggests some major characteristics associated with active learning strategies: “students are involved in more than passive learning; students are engaged in activities; there is less emphasis placed on information transmission and greater emphasis placed on developing student skills; there is greater emphasis placed on the exploration of attitudes and values; students' motivation is increased; students can receive immediate feedback from their instructor; and students are involved in higher order thinking (analysis, synthesis, evaluation).” Therefore I propose that an active learning approach should be considered as one possible innovation of teaching methods to be applied in teaching and learning activities.
3. Research Questions

The main research question:

Is there any difference in students’ achievement between those who have been taught about angles according to an active learning approach using DGS and those who have been taught in the traditional way, both in a first level of junior high school in Indonesia?

Sub-research questions:

1. Does the active learning approach using DGS help motivate students to learn geometry?
2. Do students feel that the active learning approach using DGS helps them to understand geometry?
3. Does the active learning approach using DGS help students to improve their abilities of seeing, measuring, and reasoning in learning geometry?

Expectation of the research

In this research, the researcher expected that the researcher’s intervention would make a significant difference in students’ achievement between those two classes.

The researcher also expected that the researcher’s intervention would help motivate students to learn geometry.

The researcher expected that the intervention would help students to understand geometry and that students would notice this.

Because the intervention assignments, both the paper and DGS assignments, were aimed at improving students’ abilities in seeing, measuring and reasoning, the researcher expected to
see improvements in students’ ability to recognize angles and angle patterns, to measure angles, and to reason about angles.
4. Method

4.1 Research design
There were two classes involved in this research, which were the experimental class and the control class. Both classes were at the same level of junior high school, which was the first level. However in this research, the experimental class and the control class got different treatments. The control class was taught by the researcher using the set of activities which were developed by the researcher. Meanwhile the control class was taught by the collaborative teacher using her own regular teaching method.

The researcher developed a set of activities in which students of the experimental class could learn a geometry topic about angles, doing this in a double section for each meeting. During the first section students did activities without using dynamic geometry software, and during the second section they learned geometry using dynamic geometry software. In this research the researcher used Geogebra software.

The collaborative teacher developed her own lesson activities with her own choice of mathematics books. Dynamic geometry software was not involved in these activities.

4.2 Data collection methods
To answer the main research question and the sub-research questions, the researcher used a pretest, a posttest, questionnaires, interviews, and research field notes as data sources.

Pretest and Posttest
Before the experimental teaching of the angle concept starts, both classes did a pretest; after the teaching of angles ended, both classes did a posttest. The pretest and the posttest were not exactly the same, but they were about the same topic which was geometry of angles to the extent that it was taught during the intervention.
In order to answer the main research question, “Is there any difference in students’ achievement between those who have been taught about angles according to an active learning approach using DGS and those who have been taught in the traditional way?”, the researcher compared the results of the pretest and the posttest between the experimental class and the control class.

**Questionnaires and Interview**

In order to answer to the sub research questions, “Does the active learning approach using DGS help motivate students to learn geometry?” and to answer the sub research question, “Do students feel that the active learning approach using DGS helps them to understand geometry?”, the researcher used the results of the questionnaires and interviews. The interviews involved the collaborative teacher and three students of the experimental class (individually), and the questionnaire involved all students of the experimental class.

**Findings during the intervention**

In order to answer the sub research question, “Does the active learning approach using DGS help students to improve their abilities of seeing, measuring, and reasoning in learning geometry?”, the researcher will use the findings during the intervention: journal notes, video recording of lessons, and students’ answers to pen-and-paper assignments.

To get all the data needed to answer the research questions, the researcher: (1) gave the pretest to the two classes, (2) gave an introduction of Geogebra to the experimental class, (3) taught the intervention to the experimental class, (4) collected students’ answers to pen-and-paper assignments from the experimental class, (5) wrote a journal of the taught lessons, (6) recorded the lessons on video, (7) gave the posttest to the two classes, (8) gave the questionnaires to the experimental class, (9) interviewed the collaborative teacher and three students of the experimental class, separately.
• **Giving the pretest to the two classes**

Before starting the intervention, the researcher gave a pretest to the two classes in order to investigate their prior knowledge and ability in geometry. The questions on the pretest consisted of geometry topics which students should have already known and they were to learn after doing the pretest. The researcher wanted to know whether the two classes were significantly different in knowledge of geometry before the intervention.

• **Giving an introduction of Geogebra to the experimental class**

To prepare students to use Geogebra during the intervention, the researcher organized a meeting to introduce Geogebra to the experimental students. In this meeting the researcher taught them how to use Geogebra to learn geometry.

• **Teaching the intervention**

After giving the pretest and the introduction of Geogebra, the researcher continued the next step which was teaching the intervention, teaching geometry through Geogebra to the experimental class, where there were five meetings on 5 different days, and each meeting was 2x45 minutes without any break-time. The collaborative teacher taught the control class using her own regular teaching method, and with the same allocation of time.

• **Collecting students’ answers to pen-and-paper assignments**

During the intervention, the researcher gave students pen-and-paper assignments in the first section of each meeting in the experimental class, and all students’ answers on paper were collected by the researcher.
• **Keeping a written journal**

The researcher kept a journal in which he wrote his impressions of the lesson just taught in the experimental class.

• **Video recordings of the experimental lessons**

The researcher asked the collaborative teacher to tape some videos of teaching and learning activities in the experimental class. This video record was used to add information and to support interpretation of the researcher’s journal.

• **Giving the posttest to the two classes**

After the intervention was completed and the collaborative teacher finished her teaching of the control class, the researcher gave the posttest to the two classes.

• **Giving questionnaires to the experimental students**

To get information on students’ opinion and about the intervention, the researcher asked students to answer a questionnaire.

• **Interviewing the collaborative teacher and some of the experimental students**

To get more information about the intervention which was done, the researcher interviewed the collaborative teacher and some of the experimental students.
4.3 Data analysis method

- Pretest and posttest were compared using t-test and ANCOVA.
- Questionnaire results were elaborated by devising categories for the one open question (see pages 39-40). For the closed (Likert scale) questions, for each question the students’ answers were classified as positive, negative, or neutral with respect to the intervention.
- Findings during the intervention were analyzed by comparing students’ answers to expected answers and in case of big differences: trying to understand the reasoning behind students’ answers. Difficulties that appeared more than once were noted and for each of these difficulties it was attempted to determine if students did overcome the difficulty and if so, how.
5. Research Setting and Teaching Design

5.1 The school, students, and classes

In this research the pupils to be investigated were students of junior high school in Lampung province in Indonesia, and the school was SMP Negeri 1 Candirejo. There are four parallel classes at the first level of the school. Students in each class were grouped randomly by the school administration at the start of the academic year, regarding various abilities of students, which were lower, middle, and higher achiever. The ages of students in this level were about 13 and 14 years old.

From these four parallel classes, two classes were chosen to be involved in this research. They were chosen because the collaborative teacher only had opportunity using the computer laboratory in their learning time without disturbing other classes’ schedules. From these two classes, one was randomly chosen as the experimental class and the other as the control class; each class had 36 students.

The experimental class was the class taught geometry with the intervention. Meanwhile the control class was the class taught geometry with the traditional teaching method that the collaborative teacher always used in her teaching. The intervention in this research involved teaching geometry through the active learning approach using dynamic geometry software, Geogebra, and the regular teaching method was teaching geometry through the traditional teaching approach without Geogebra.
5.2 The researcher’s role and the collaborative teacher’s role

There were five meetings of teaching geometry through Geogebra to the experimental class. In the intervention there were always two consecutive sections in every meeting, which were the first section without Geogebra, and the second section with Geogebra. In each section, all activities were student centered, which means the researcher just gave the tasks without giving a lecture about the topic that students would learn, but the researcher gave some help and hints to students who had a problem when doing the tasks. At the end of each meeting the researcher always gave an explanation and emphasized what students just learned and did in each section to make students better understand what they could take home from the learning activities.

For instance, the researcher gave a task for students to recognize and to measure a straight angle. Instead of using direct teaching and telling students that a straight angle is $180^\circ$, the researcher preferred to give students guiding questions which were displayed one by one on the wall through a projector. The first question was “do you remember how many degrees is in one full rotation of a circle?” Actually, this question was planned to be done privately by each group, but because many students did not remember, the researcher asked this question openly of the whole class. And the researcher just confirmed the correct answer received from one of students. The researcher then displayed a picture of a diameter AOB and asked students the next question, “how many degrees is angle AOB?” In this strategy, the researcher always tried to make students more active in exploring their own thinking.

The collaborative teacher in each of the researcher’s intervention meetings just assisted the researcher in taking some pictures, taping some videos, and giving some feedback to the researcher after each meeting. Meanwhile the researcher did not have any contribution to the collaborative teacher’s class, which was the control class, because the collaborative teacher objected when the researcher asked to observe her class during her teaching. However the researcher already knew her teaching method from a telephonic interview conducted before the start of the research as well as from various talks during
the intervention period. Her teaching method was not different from most mathematics teachers’ teaching method in my region. In her teaching, at the beginning of the class she gave a lecture of the topics she wanted to teach, and after that she gave students some examples of questions with the answers, and then she continued asking students to answer some questions similar to the examples. She also used some discussion during her teaching, but mostly all activities were teacher centered.

5.3 A Teaching Design for the Subject of Angles

For the experimental class, a series of assignments was developed, aiming at the concept of angle. The design of these assignments (see appendix xxx) as well as their intended use will be described below. In the first meeting the researcher taught students how to recognize an angle shape and what the definition of an angle is. Mathematically, a common definition of an angle is a shape, formed by two lines or rays diverging from a common point (the vertex of an angle). To teach this definition to students, in the first section of a meeting the researcher asked students to recognize an angle shape by putting together two end points of two small sticks which they brought into the class. In this task the researcher hoped that students learned that from real things they could create an angle shape. Meanwhile in the second section with Geogebra, students were asked to draw two segment lines and to put the end points of two segment lines together, so as to create an angle. In this activity the researcher hoped that students could see the visualization of attributes of an angle. These are the attributes of an angle that students were supposed to learn: a vertex, legs, interior, and exterior of the angle. The definitions of each attribute are described below:

- The vertex of an angle is the common point at which the two lines or rays are joined.
- The legs (sides) of an angle are the two lines that make it up.
• The interior of an angle is the space or the area between the rays that make up an angle, and extending away from the vertex to infinity.

• The exterior of an angle is all space on the plane that is not the interior.

In the researcher’s opinion, by using Geogebra tools students should be able to recognize all the attributes of an angle in an easy way, because Geogebra provides tools to help students to construct and to recognize all those attributes, which could not be recognized easily by shaping an angle from two small sticks in the section without Geogebra, especially since students do not see any visualization of points of an angle formed by two small sticks (see picture 5.1 and picture 5.2).

![Picture 5.1 An angle BAC constructed by Geogebra](image1)

An angle BAC in the picture above is really clearly showing a corner point A, two segment lines of AB and AC, and an area of angle BAC (colored area).

![Picture 5.2 An angle constructed by two small sticks](image2)
In picture 5.2, the researcher thinks that students only can recognize an angle shape, but they do not see a concrete image of end points, vertex and area of an angle. Even though drawing an angle can be done in the traditional way using a ruler, in the researcher’s opinion, drawing an angle using Geogebra tools gives students another experience which is different from what they are used to. After the students were able to shape an angle, then they would learn how to identify an angle by its own name based on the names of points of the angle. There are two ways to identify an angle which are like this: (1) ABC (the angle symbol, followed by three points that define the angle, with the middle letter identifying the vertex, and the other two indentifying points on both the legs), or (2) B (just by the vertex, as long as it is not ambiguous). Based on the researcher’s experience in teaching mathematics, a lot of students make mistakes in naming an angle, for example, when they are asked to draw angle ABC, they draw an angle BAC, and when they are asked to name an angle from a pictured angle BAC, they name it as angle ABC. By using Geogebra tools, students will easily recognize these mistakes, because Geogebra tools automatically measures an angle after the student identifies it by clicking three points in the right order. (See picture 5.3 and picture 5.4)
After students were able to name an angle, the next topic was measuring an angle in degrees, where a full circle is $360^\circ$ degrees. (See picture 5.5)

For very small angles, the degree is further divided into 60 minutes, and for even smaller measurements the minute is divided again into 60 seconds. The last measure is very small, and it usually is used where angles are subtended over extreme distances such as astronomical measurements, and measuring latitude and longitude on earth. However, in this research the researcher only taught students the size of an angle in degrees, but not in minutes, nor in seconds.
In geometry, there are some well known types of angles as listed below.

- Null angle, any angle which has the size of exactly $0^\circ$.
- Acute angle, any angle which has a size between $0^\circ$ and $90^\circ$.
- Right angle, any angle which has the size of exactly $90^\circ$.
- Obtuse angle, any angle which has a size between $90^\circ$ and $180^\circ$.
- Straight angle, any angle which has the size of exactly $180^\circ$.
- Reflex angle, any angle which has a size between $180^\circ$ and $360^\circ$.
- Full angle, any angle which has the size of exactly $360^\circ$. (Actually, it is the exterior angle of a null angle or vice versa)

The visualizations of each type are shown below.

![Picture 5.6 Types of angles]

Based on the researcher’s experience as a mathematics teacher, students sometimes are confused when trying to distinguish between null angle and straight angle, because both of them look similar to a straight line. The researcher developed lesson activities in which students were asked to measure both angles by using a protractor in the first section without Geogebra, and using Geogebra in the second section. After students did some experimental measurements of a null angle and a straight angle, the researcher expected that they would see the difference between those angles. (See picture 5.5 and picture 5.6)
A null angle has a corner point which is not lying in between the other points of the null angle (picture 5.8). Meanwhile a straight angle has a corner point which is lying in between the other points of the straight angle (picture 5.7).

Actually when used in geometry, angles have some extra properties, in which they can have a size larger than 360°, can be positive and negative, and are positioned on a coordinate grid with x and y axes. In that situation they are usually measured in radians.
instead of degrees. One radian is the angle made at the center of a circle by an arc whose length is equal to the radius of the circle. (See picture 5.9)

A full circle has $2\pi$ radians, and a full circle also has exactly $360^\circ$, so that each radian comes out to approximately $57.296^\circ$. However in this research the researcher did not teach the extra properties described above to the students, because they are not included in the mathematics curriculum of the first level of junior high school. Other angle topics that the researcher taught were the relationships of angles. In geometry, there are some angle relationships as listed below.

- **Adjacent angles**

  The definition of adjacent angles is: two angles that share a common side and a common vertex, but do not overlap.

  In the researcher’s opinion drawing adjacent angles using Geogebra tools is much easier than using a protractor, and also the measurement of the angle size is much more precise. The researcher developed tasks about this topic in the sections with and without Geogebra, in which students were asked to draw some adjacent angles. After doing the tasks about adjacent angles, the researcher hoped that students understood that to draw adjacent angles from two given angles they must put the first leg of the second angle on the second leg of the first angle.

  An example of adjacent angles is like below.
In angle DAC, AD is the first leg and AC is the second leg. Meanwhile, in angle CAB, AC is the first leg and AB is the second leg (counterclockwise). Angle DAC and angle CAB are adjacent angles, because they share a common side which is the segment line AC, and they share also a common vertex which is the point A, but they do not overlap. After students were able to draw adjacent angles, the researcher hoped that they realized that the sum of the two adjacent angles is the size of angle BAD.

- **Complementary angles**
  The definition of complementary angles is: two angles that add up to $90^0$.
  To find a complementary angle in degrees for an angle given as a figure is not easy because students need to measure and to calculate carefully instead of just drawing. There are two possible ways that students could use to find complementary angles. The first one is that students could try to add some angles until the two angles add up to $90^0$. The second is that students would directly subtract $90^0$ by the given an angle as measured, then students would get the complementary angles. Those two possibilities could be done by calculating or by drawing the angles in combination with at least one measurement. Again, if students do this task using Geogebra, then it will be easy for them to get the solution because in Geogebra both drawing and measuring are easier.

- **Supplementary angles**
  The definition of supplementary angles is: two angles that add up to $180^0$.
  In the researcher’s opinion, if students do not have a problem in understanding and doing questions about the complementary angles, then students should not get a
problem in understanding supplementary angles either. However, based on the researcher’s experience, students sometimes made mistakes by mixing up the two words, “complementary” and “supplementary”. For example, when students were asked to find complementary angles, they gave an answer which was supplementary angles.

- Opposite angles

The definition of opposite angles is: a pair of non-adjacent angles formed by the intersection of two straight lines.

The researcher argues that besides remembering the definition of opposite angles, students should also be able to recognize opposite angles by the picture of opposite angles to help students better understand them. In the researcher’s opinion, visualization of some definitions in mathematics can help students to understand these definitions.

An example of opposite angles is shown below.

![Picture 5.11 Opposite angles](image)

The two straight lines above intersect at one common point which is vertex Q, and form four angle spaces. Angle JQL and angle KQM are opposite angles because they are non-adjacent angles in that picture. The same applies to angle JQM and angle KQL which are also un-adjacent angles. Therefore they are another pair of opposite angles.(see picture 5.11). The researcher expects that after students draw two lines intersecting at a common point like picture 5.11, they will realize that opposite angles always have the same sizes.

- Corresponding angles
Corresponding angles are formed where a transversal crosses other lines. A transversal is a line that cuts across two or more lines. The corresponding angles are the ones at corresponding locations at each intersection.

In the researcher’s opinion, this relationship of angles is much more difficult than the previous relationships, because the definition and the visualization of the definition are a bit complicated to understand. Visualization and examples of the definition are really important to help students understand, especially to students of junior high school level.

![Picture 5.12 Corresponding angles](image)

An example of corresponding angles in the picture above is a pair of angles AEP and AFR. In the case of a transversal cutting across a pair of non-parallel lines, corresponding angles have no particular equality relationships.

If the transversal cuts across parallel lines, then corresponding angles have a unique relationship, which is that they have the same size. The example of that case is shown below.

![Picture 5.13 A transversal cutting across parallel lines](image)
In the above case, PQ and RS are parallel lines that are cut by the transversal AB. Therefore angle AEP and angle AFR have the same size, because they are corresponding angles in the picture above. Analogous remarks can be made about other pairs of corresponding angles.

There are other particular angle relationships that occur in the case when the transversal cuts across two parallel lines, which are alternate interior angles, alternate exterior angles, interior angles of a transversal, and exterior angles of a transversal.

Alternate interior angles are pairs of angles that are inside the parallel lines, and on opposite sides of the transversal. Each pair has the same measure. An example of alternate interior angles is shown below.

![Picture 5.14 Alternate interior angles]

The picture above shows that angle PEB and angle AFS are a pair of alternate interior angles, and they have the same measure.

Alternate exterior angles are pairs of angles that are outside the parallel line and on opposite sides of the transversal. Each pair has the same size. An example of alternate exterior angles is in the picture below.
Picture 5.14 Alternate exterior angles

Angle AEP and angle BFS shown in the picture above are a pair of alternate exterior angles.

Interior angles of a transversal are pairs of angles that are inside of the parallel lines and on the same side of the transversal. Each pair of angles has a sum of 180°. An example of a pair of interior angles of a transversal is shown below.

Angle BEQ and angle AFS are a pair of interior angles of a transversal in the picture above.

Exterior angles of a transversal are pairs of angles that are outside the parallel lines and on the same side of the transversal. Each pair of angles has a sum of 180°. An example of exterior angles of a transversal is shown below.
The two angles AEP and BFR is a pair of exterior angles of the transversal in the picture above.

In the researcher’s opinion, even though all the relationships can be drawn by using a ruler and a protractor, students will easily be able to draw and to investigate many kinds of those relationships through Geogebra, because Geogebra provides a dragging tool to move any object in the above pictures. By dragging any point of the pictures students will see the sizes of angles automatically changing along with changing measurement results for these angles, so the researcher hoped that after seeing the changing of angle sizes, students would be able to compare and investigate the behavior of the various relationships.
6. Findings and Data Analysis

In this chapter, the researcher will analyze data and findings during the intervention. First of all, the researcher will analyze the pretest results of the control class and the experimental class to see whether both classes are different or not in their pretest results. After that, the researcher will analyze their posttest results to see whether there is a difference between both classes in their posttest results. The next step is that the researcher analyzes whether the pretest results and the treatment significantly predict the posttest results. After that, the researcher is going to analyze findings of posttest questions to know whether there is a significant effect from the pretest results and the treatment on students’ answers to each posttest question.

After finishing with the pretest and the posttest data, the researcher will continue to analyze questionnaire findings to see whether students of the experimental class give positive or negative opinions about the intervention. After that, the researcher will analyze interview findings to see whether the collaborative teacher and three students of the experimental class say positive or negative statements about the intervention.

Finally, the researcher is going to analyze findings of meetings during the intervention in the experimental class to see how students of the experimental class were affected by the various activities. All the steps of analyzing data and findings are described below.

6.1 Pre-test

On the pre-test, the control class and the experimental class took the same test questions which were asking about their previous knowledge and the topic of geometry that they would learn after the test. Before the pretest, the researcher did not know whether both classes had the same level of ability in geometry.

The pretest results give information that the control class reached the score-mean 64.69, meanwhile the experimental class got score-mean 67.58 out of the maximum score (140).
The score-means show that the experimental class did better than the control class did in the pretest. It shows that difference between the means of pretest results is \textbf{2.89}.

To know whether they were really similar or not, the independent-samples t-test is used to investigate it.

The outcome gives information that the Levene’s test for equality of variances shows that the value $F(1.461)$ is not significant (0.237) which means that there is no significant different in the variances of the two classes, therefore in this case we may assume equal variances.

Under this assumption the t-test gives a significance value (2-tailed) of \textbf{0.474} which is more than 0.05, therefore there is no significant difference between the means of the two classes.

The outcome says that even though the experimental class got the score which was better than the control class, they were not significantly different.

\textbf{6.2} Post-test

The post-test was held after both the researcher and the collaborative teacher finished teaching their lesson material to the classes. Although both the pretest and the posttest were about the subject of angles, the questions were different. We had no intention to compare the pretest and the posttest directly.

The posttest was given to investigate whether there is any significant difference between the experimental class and the control class after the intervention. And to investigate the question the independent-samples t-test is used in this case as well.

In the posttest results the experimental class reached the score-mean \textbf{64.49}, meanwhile the control class got a score-mean \textbf{49.49} out of the maximum score (150). It shows that the
experimental class did better than the control class did, with a difference of **15.00** between the means.

The outcome of the independent-samples t-test shows that under the Levene’s test for equality of variances the value $F (0.413)$ is not significant ($0.522$), which means that there is no significant difference between the variances of the two classes. Therefore we may assume equal variance.

Using that assumption, the t-test for equality of means shows a significance (2-tailed) of 0.004 which is less than 0.05, therefore there is a significant difference between the means of the two classes. It is a lot more significant than the researcher hoped for.

The outcome of the independent-samples t-test of the posttest results tell us that the experimental class did better than the control class in the posttest.

**6.3 Analysis of the pretest, the posttest, and the treatments.**

The pretest and posttest design in this research is used for comparing the two classes (the experimental class and the control class) in their achievement in learning geometry after they got different treatments (different teaching methods).

In the previous data analysis the control class and the experimental class are not significantly different in their pretest score-means, but after each class got different treatments (teaching methods in learning geometry), they become significantly different in their posttest score-means.

To investigate whether the posttest score is predicted by the pretest score and the treatment, an ANCOVA test is used to analyze it.
In this test the posttest score is the dependent variable, meanwhile the treatment is taken as the fixed factor, and the pretest score is used as the covariate.

The outcome of ANCOVA test gives information that the pretest score (covariate) significantly predicts the dependent variable (the posttest score), because the significance value (0.000) is less than 0.001.

The ANCOVA also shows that the effect of the treatments on the posttest is significant, because the p value is 0.004 which is less than 0.01.

The outcome of pairwise comparisons shows that the mean difference of posttest scores is significant at the 0.01 level. It means that the treatment significantly affects the posttest, after correcting for the (small) initial difference between both groups.

From the ANCOVA outcome we can say that the posttest result was influenced significantly by the pretest score and the treatments, and that the intervention has a positive effect on the achievement of the experimental students.

6.4 Findings of each of the posttest questions
The ANCOVA for each of the separate questions is shown below, with the required p-value = 0.05/15=0.0033 to all questions, and with the p-value = 0.05/6 ≈ 0.0083 to questions 1, 2, 3, 6a, 6b, and 9, because the researcher expects that the experimental class will do better than the control class does for each question, and the experimental class is expected to be much better than the control class especially in answering questions 1, 2, 3, 6a, 6b, and 9. A Bonferroni correction was used to lower the p-value criterion appropriately, such that in total, the chance of incorrectly finding a significant difference would not rise above 0.05 for each of these two classes of questions.
From the table in the appendix B4, no one of questions 1, 2, 3, 6a, 6b, and 9 shows that the intervention has significantly affected the experimental class, by the $p$-value = 0.0033 or even by the $p$-value = 0.0083. However, on question 9, the result shows that the pretest result significantly predicts the posttest result. Question 9 asks students to recognize some angles and to find out their size, where some concepts are necessary to answer this posttest question and some of these concepts were questioned in the pretest. It means that the better the pretest results the better the posttest result for question 9.

Only questions 4b and 5a show that the intervention has significantly affected the experimental class by the $p$-value = 0.0033, where the experimental class did better than the control class did. The question 4b asks students to investigate which lines are unparallel lines from the picture given, and the question 5a asks students to investigate how many angles can be recognized from the picture given (see appendix K). In the intervention, the experimental class actually had opportunities and experiences to deal with kinds of questions like 4b and 5a. Therefore when they faced questions 4b and 5a, they did not really find it difficult to answer the questions.

There are two questions (1 and 6a) in which the control class did better than the experimental class did, but it is not significantly different. Even though this case is not significant, it shows that the experimental class has a weakness in some parts comparing to the control class. Overall the experimental class did better than the control class in all other questions.

6.5 Questionnaire findings

6.5.1 Findings of question 1: What do you think about Geogebra?

To analyze the question 1, the researcher used three categories of students’ opinions about Geogebra, which are:

1. Easy
   1. “Easy”: Geogebra is easy to use to learn geometry
2. **Helpful**
   1. “Helping to understand”: Geogebra helps students to understand geometry
   2. Others: Helpful in various ways.

3. **Motivating**
   1. “Enjoyable”: Geogebra makes learning geometry more enjoyable
   2. “Fun”: Geogebra is fun to use to learn geometry
   3. “Helping to motivate”: Geogebra helps students to motivate themselves to learn geometry
   4. “Interesting”: Geogebra is interesting to use to learn geometry

From the results of students’ answers in the appendix C1, the researcher makes a table like below.

<table>
<thead>
<tr>
<th>Easy</th>
<th>Helpful</th>
<th>Motivating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal</td>
<td>Help to understand</td>
<td>Others</td>
</tr>
<tr>
<td>20 (57%)</td>
<td>28 (78%)</td>
<td>14 (40%)</td>
</tr>
</tbody>
</table>

**Table 6.1 Questionnaire Result of question 1 (N=35, see appendix C).**

From the table 6.1, in the first category 57% students say that Geogebra is easy to use to learn geometry.

In the second category, 86% students say that Geogebra is helpful for learning geometry, in which there are 78% students say that Geogebra help them to understand geometry and there are 40% students say that Geogebra is helpful in various other ways.
In the third category, 71% students say that Geogebra is motivating; in which 23% students say that Geogebra makes learning geometry more enjoyable; 60% students say that Geogebra is fun to use; 17% students say that Geogebra helps to motivate them to learn geometry; and 6% students say that Geogebra is interesting to use.

From these findings, the researcher concludes that each of the three positive points (easy, helpful, motivating) is expressed by more than 50% of the students.

### 6.5.2 Findings of questions 2-11

From the table in appendix C2, the researcher classifies students’ statements in the table 6.2. There are three classifications here, which are “Positive”, “Neutral”, and “Negative”. The “Positive” includes all students’ answers which agree with positive or contra negative statements. The “Neutral” includes all students’ answers which neither positive nor negative statements. Meanwhile the “Negative” includes all students’ answers which negative or contra positive statements. For example, if a student agrees with “Geogebra can help motivate me to learn geometry”, it means that the student agrees with a positive statement. However, if a student disagrees with such a statement, then it means that the student agrees with a contra positive statement.

<table>
<thead>
<tr>
<th>No</th>
<th>Questionnaire</th>
<th>Positive</th>
<th>Neutral</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Geogebra can help motivating me to learn geometry.</td>
<td>94.3</td>
<td>5.7</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Geogebra helps me to understand about geometry</td>
<td>97.1</td>
<td>2.9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>much better.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Learning geometry through Geogebra is fun and easy.</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Geogebra makes me confused about geometry.</td>
<td>80</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Geogebra is difficult to use when learning geometry.</td>
<td>83</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Geogebra takes a lot my time if I use it for learn</td>
<td>66</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>geometry.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Learning geometry through Geogebra is useless.</td>
<td>97.1</td>
<td>0</td>
<td>2.9</td>
</tr>
</tbody>
</table>
From the table 6.2 above, the researcher could say that 79% students have a positive opinion towards Geogebra, 18% students have a neutral opinion towards Geogebra, and 3% students have a negative opinion towards Geogebra. Based on these findings, the researcher concludes that learning through Geogebra had a positive effect on students. This can be supported by students’ statements, which 94% students agree that Geogebra could help motivate them to learn geometry and 97% students agree that Geogebra helps them to understand geometry much better.

**6.6 Interview findings**

**6.6.1 Findings of the collaborative teacher’s interview**

Based on the interview with the collaborative teacher (see appendix D1), the researcher got some findings, which are some positive effects of the intervention towards students of the experimental class. The students of the experimental class had become more confident, more critical, and also more enthusiastic in learning mathematics. They have been motivated by the intervention in which they got the new and the first experience of learning mathematics through computers, especially learning geometry through Geogebra. Actually, the collaborative teacher is interested in continuing teaching geometry through Geogebra but there are some technical problems that make her unable to continue it. But she has the willingness to do it in the future when all the technical problems are solved.
There are some reasons why she wants to do it. One of the reasons is that she agrees with Geogebra being easy to use and to understand geometry, and the other reason is that she realized that there have been some positive effects her students got after the intervention. She also considered the special case that the collaborative teacher mentioned in the interview, which is the case of Sindi, showing that the intervention had changed Sindi’s behavior towards mathematics from a common student to a talent student in mathematics.

6.6.2 Findings of the experimental students’ interview

Based on the interview of the three experimental students (see appendix D2), the researcher concludes that Geogebra is a good software to help students in learning geometry, because it helps students to understand geometry, motivates them in learning geometry, helps them training their skills in reasoning, intuition, and measuring, and also makes learning geometry fun and enjoyable. Actually students did not have any problem to learn Geogebra and used it to learn geometry, but the problem was only the total of computers in laboratory which were not sufficient to support each student to explore and to experience more, because students should take turns to use a computer.

6.7 Intervention Findings

There were five meetings in the intervention. During each meeting sometimes the researcher helped some students or some groups to guide them and to give some hints to overcome problems in doing the tasks without giving them a direct correct answer, in other words the researcher just tried to make students more confident and more engaged in learning activities without disturbing their own attempts to explore and to learn using their own thinking. However, at the end of each meeting the researcher always gave some explanation about the correct answer and also discussed the problems that students were facing during doing the tasks to make students better understand what they just did and what they learned.
6.7.1 The First Meeting

In the first meeting the students were grouped in 6 groups of 6 students in each group, because there were only 6 computers available to use in the lab. There were two sections in the first meeting, which were a section without computer use, and a section with computer use.

6.7.1.1 Section without computer use

In this section the researcher was starting by giving a little introduction about what students would do in the first section and the second section, which they would do some paper works without using computers in the first section, and do some tasks with using computers in the second section. After that the researcher was showing a transparent block. The researcher asked students a question: do you know what it is? Even though not all students answer the question, the researcher hoped that all students knew what it is, because some students could answer the question, which they answered: it is a block. After that, the researcher distributed the lesson materials to each group. Each group was asked to discuss and answer some questions, and the results are shown below.

Question 1

1. Please look at the picture below:

- How many corner points (meeting points of edges) are there in the block above?
The aim of this question is: students will be able to identify the corner points of the block, and the expected answer is: there are 8 corner points.
In this question only one group could not answer well, while 5 groups gave the correct answer, which is 8 corner points. It shows that there is a group that did not understand what the corner point means. However, it is still interesting to try interpreting what the students meant by the incorrect answer they gave, which is there are 24 corner points. The students might consider that because each point has 3 edges shaping a corner point and there are 8 points at the block they see, then they just multiply 3 by 8 that equals to 24. For example, when the students see that the point A has 3 edges.

And then they see there are 8 points in total, then they just simply multiply 3 by 8 which equals to 24.
It means that some students misunderstood in interpreting the question. However, the researcher still concludes that students did not find difficult it to answer this question, because almost all groups could answer the question correctly.

b.  *How many edges are there meeting at every one corner point?*

The aim of this question is: students will able to understand that the corner point is the meeting point of some edges of the block, and the expected answer: there are 3 edges that meet at every one corner point.
In this question almost all groups answered 3 edges, because there is only one group answering 2 edges. Actually, 2 edges is not the best answer, but it could be the group just considering that 2 edges are enough to make or to create an intersection point or a corner point, so it is still acceptable in the researcher point of view. The researcher concludes that students did not find difficult to answer this question.

c.  *Write down a group of edges that meet each other at a corner point.*
The aim of this question is: students can identify the name of every edge that meets at one common corner point, and some possible answers are: the first group is AB, AD, and AE; the second group is BA, BC, and BF.

In this question there is only one group giving a correct answer, which is BA, DA, and CA. One group answered not really complete as the researcher expected, this group just wrote edge AB meets with BF, but it is still acceptable, because those edges create a common corner point. Meanwhile the rest of the groups gave incorrect answers. Actually this question was not expected to be difficult by the researcher, but unfortunately most students found difficult to answer well this question. The researcher supposes that students did not yet know how to write a name of an edge. This is shown by two categories of their answers, the first one is that they wrote edge E meets with H, F, A. In this case the researcher tried to catch what they meant by considering this answer as meaning: edge EH, edge EF, and edge EA (two groups gave such an answer). And the other incorrect answer is a corner point A meets with BDE, which the researcher try to interpret the meaning as a group of edges AB, AD, and AE. Besides the correct answer and the two categories of answers that the researcher could interpret as notational difficulty, there is a group which just wrote BF, which the researcher is not able to analyze, in other words one group did not understand the question.

d. Write down three pairs of edges that do not meet each other.

The aim: students will be able to investigate the edges that are not meeting at one common corner point, and an example of an expected answer: 1st pair is AB and CD; 2nd pair is BC and EH; and 3rd pair is AB and EH.

In this question there are three groups giving correct answers, and three groups gave incorrect answers. Some students did not yet know how to write an edge. The researcher found some answers which show that students did not really understand which one is an edge of the block and which one is not. One of the incorrect answers is AC, BF, and CG, which shows that students considered AC as an edge of the block. The researcher found that they did not yet know how to distinguish between an edge and a
diagonal, because they mixed edges BF and CG with a diagonal AC. And it shows as well that students did not pay attention that actually between AC and CG there is a common point C. The other interesting incorrect answer is CE, GA, and HB, which looks like a correct answer if we just see the letter of each point, then there is not a common point between them, but when we pay attention more, there is a mistake. The mistake is that they are not edges of the block, and actually they meet in the middle of the block (two groups had such mistakes).

e. **Please give a reason why some edges can meet at a common corner point.**

The aim of this question is: students will be able to give their reasons and show their understanding about the relationships of edges that meets at one common corner point, and the expected answer is: there are some edges meeting at corner points because they are not parallel to each other and they are on the same plane.

In this question no one of groups gave the correct answer the researcher expected, which is that the edges must be unparallel and must be on the same plane. It shows that students still did not really understand what characteristics of edges determine if they can meet at a common point. This shows that students did not yet know how to give a reason in mathematics and also they did not yet know how to give a general answer, without reference to any specific situation. Some students wrote answers that had nothing to do with the question, for instance, they wrote: because HDC meets an angle. Other students just answered by repeating similar words as used in the question, such as because the edges meet at a common point.

f. **Look carefully at edges that do not meet at corner points. For example, the relationship between AB and EF, and also between AE and CD. What is your conclusion on the relationship of those example pairs of edges?**

The aim of this question is: students will be able to formulate in their own words the two relationships between edges that do not meet at one common corner point, and the expected answer is: AB and EF are parallel and they do not meet at any point at all.
AE and CD are not parallel, they are not at the same face, and they do not meet at any point as well. The conclusion is that two edges will not meet each other not only for one possible reason which is that they are parallel, but also there is another possible reason, which is that they are not parallel and not at the same face as well. The edges like AE and CD are called crossing-lines or crossing-edges. (But this name was not yet mentioned to the students)

In this question four groups gave the correct answer, writing similar words like AB and EF are parallel edges, meanwhile AE and CD do not intersect and are not parallel, which is called crossing edges. One group did not give any answer at all, and one group gave an answer which needs the researcher to interpret the answer, because the group just wrote, those lines do not connect with each other and are crossing. The researcher tries to understand the meaning of the answer as those lines do not connect = AB and EF do not meet at a common point that means they are parallel lines, meanwhile and crossing = AE and CD are crossing each other. In this case the researcher considers that students understand the question and know the answer, but they could not write it in the appropriate ways.

g. *How many possibilities of relationship between two edges of the block are there?*

The aim of this question is: students will be able to know all the possibilities of relationships between edges of the block, and the expected answer: there are 3 possibilities of a relationship between 2 edges of the block, which are 1\textsuperscript{st} parallel edges, 2\textsuperscript{nd} intersecting edges, and 3\textsuperscript{rd} crossing edges.

In this question there are only two groups giving the correct answer. The researcher is a bit surprised, because this question should be easy if the question f could be answered well. In fact there is a contrast because only 2 groups did well at the question g, whereas there are 4 groups who did well at the question f. One example of incorrect answers students gave is that students just wrote: there are many possibilities AB, BF, AD, EH, FG, HG, and DC. This answer shows that students did not understand the question.
h. **Write down your conclusion of your observation at the picture above, when do two edges meet at one point, and when do two edges not meet at one point?**

The aim of this question is: students will able to make their final conclusion on what they have just learned during class activities, and the expected answer: two edges will meet at one common point if they are not parallel and they are on the same face. Two edges will not meet at one common point if they are parallel, or they are not parallel but not on the same face.

In this question no one of the groups gave the correct conclusions. All students’ answers had nothing to do with the question. One example of students’ answer is: A. because having two points which meet and having some edges, B. because having no unparallel edges and crossing. This answer is far from what the researcher expected, and it shows that students did not know how to make a general conclusion from what they just learned. The researcher concludes that question f, which asked about relationships between specific lines, was much easier than questions g and h, which asked for generalizations.

**6.7.1.2 Section with computer use**

In this section the researcher allowed students to use a computer to play with Geogebra. Because there were only six computers in the computer lab that could be used, students were grouped in groups of 6. Even though this condition was not really good enough for students, they were still engaged and enjoyed learning geometry through Geogebra. After grouping the students, the researcher started to give them some tasks which were related to the previous section. In the second section of every meeting, the researcher did not ask students to work on paper, so all descriptions below are based on the researcher’s observation notes and some video tape that the collaborative teacher took during the class. What they did in this meeting is described below.
1. **Draw a pair of parallel lines.**

![Image of parallel lines](image.png)

The expectation of this task is that students will learn and realize that from a point outside a line, there is only one line that can be drawn which is parallel to the first line.

This is the first meeting where the students dealt with Geogebra in learning geometry, after they got a little introduction of Geogebra on the previous day. At the beginning of this section, some groups still found difficult to use Geogebra tools to draw a pair of parallel lines like in the picture above, therefore the researcher taught the students the needed steps to draw the parallel lines. First of all, the researcher asked them to draw 3 different points, and after that asked them to make a line between 2 points they drew and leaving 1 point free. All groups could follow the instructions well, and after that the researcher asked students to draw a line which is parallel to the first line through a free point outside of the first line. All these steps still aimed at learning to use Geogebra. After they had drawn the picture, the researcher asked them to draw another line from the same point which is also parallel to the first line, but they could not make it, because every time they try to draw another line from the same point, the picture was still the same. The researcher asked them a question: can you make another parallel line from that point? Based on their work the students answered, no we cannot. The researcher
asked another question, so how many parallel lines you can draw from that point? The students answered, only one line.

2. **Draw a pair of perpendicular lines**

![Image of Geogebra software with a line and a perpendicular line drawn through a point.]

The aim of this task is that students will understand and realize by themselves that from one point outside of a line, there is only one line which is perpendicular to the first one. Just like the previous task, students were still struggling to draw a pair of perpendicular lines through Geogebra, but they did well after some attempts. Like the previous task, the researcher also asked them the same question which was asking them to draw another line, and they found the same condition where the picture remained the same. Before continuing to the next question, the researcher emphasized what the students just made, which was they just found out that only one line can be drawn perpendicular to a second line through a given point.
3. Please draw a picture like below

![Image of parallel lines and perpendicular lines]

The aim of this task is that students will learn that two different pairs of parallel lines, when they are perpendicular to one another, create a rectangle.

After students understood and knew how to draw parallel lines and perpendicular lines, they were continuing to draw a picture like above. First of all, the researcher asked them to draw a pair of parallel lines. The researcher asked them to draw two different points on one of the parallel lines. After that the researcher asked the students to draw perpendicular lines to that line from those two points. And the students did it. After they were done drawing the picture, the researcher asked them, what shape do you see when all the intersection points are connected? The students answered, it looks like a rectangle. After confirming the answer is correct, the researcher asked another question, based on what you just did through Geogebra to draw the picture above, what lines are used in constructing a rectangle? Students answered: parallel lines and perpendicular lines.
4. Please draw a picture like below

![Image of a grid with intersecting lines]

The aim of this task is that students learn and realize that from a point more than one line can be drawn.

After finishing the task 3, students were asked to continue to draw a picture like above. The researcher asked students to draw a pair of parallel lines through two different intersection points. After students drew the picture, the researcher asked this question to students: Look at your own picture. How many lines have you drawn from each intersection point? The students answered, some points have 2 lines, and some points have 3 lines. And the researcher emphasized to the students that the students just learned that from a point they can draw more than one line.
5. *Please draw a picture like below*

The aim of this task is that students realize only unparallel lines which are on the same plane can intersect each other at a common point.

Without deleting the picture that students had drawn in the previous task, students were asked to continue to add another line like in the picture above. After they finished drawing the picture, the researcher asked them to look at their own picture and asked them these questions: Look at lines that meet at every intersection point. Are they parallel or not? The students answered, no they are not parallel. And the researcher asked another question, are they on the same plane? The students answered, yes they are. The questions were addressed to emphasize students understanding that lines will intersect each other if they are unparallel and on the same plane.
6. *Please draw a picture like below*

![Image of Geogebra window with lines]

After doing the previous task, students were asked to continue drawing another line like in the picture above. In this task, the researcher just wanted them getting used to draw lines using Geogebra. This aim was reached because the researcher saw that students did not seem to have any problem anymore in using Geogebra tools for drawing lines.

7. *Please draw a picture like below*

![Image of Geogebra window with lines]

The next task was asking students to complete their picture by drawing two lines like in the picture above. In this step, the researcher asked them to guess what construction
they were just doing. But no one student could guess well, they just said we’re just
drawing some parallel lines and some unparallel lines. Actually, the researcher hoped
they could guess that they were just constructing a cube or a block.

8. Using the last picture you have drawn, please make it like below

![Geogebra Cube](image)

After students completed drawing the picture in the previous task, the researcher asked
them to use other Geogebra tools, to make their picture like the picture above. It was
taking a bit of time, because they should be careful in making all lines disappear first,
and leaving some points as needed. After that, students were asked to connect all
points so that the picture like above appeared. In this task, the researcher hoped that
students learned how to work carefully in constructing a geometrical shape through
Geogebra, and also they learned that a cube is constructed by parallel lines and
perpendicular lines.

9. What is the picture that you have drawn?

After the final picture was drawn, the researcher asked students: what is the picture
that you have drawn? The students answered, it is a cube. After that the researcher
asked another question, do you see parallel lines and unparallel lines in your picture?
The students answered, yes we do. The researcher asked the questions to emphasize that in a cube there are parallel lines and perpendicular lines, as they learned from the first section of the first meeting.

6.7.1.3 Conclusions of the first meeting

In the pen-and-paper section, most students did not find it difficult to recognize corner points of a block, and they also did not have problem to recognize how many edges meet at a corner point. However, at the question 1c, most students had difficulty to name edges which meet at a corner point. They, possibly, did not yet know how to name an edge correctly. To overcome this problem, before displaying question 1d, the researcher gave some examples of how to name an edge, without directly giving the answer to question 1c. And then, the researcher saw that most students showed an improvement in naming edges of a block at the question 1d, but a new problem came up, which was that some students could not distinguish between an edge and a diagonal of a block. To overcome this problem, the researcher gave an explanation how to distinguish an edge and a diagonal of a block at the end of the first meeting. The researcher hoped that students would understand more about that by learning from their own mistakes and getting a correct explanation from the researcher. At the question 1e, the researcher found that all students did not yet know how to give a reason in mathematics. At this stage, the researcher just encouraged students to give their own reasons and arguments, no matter if it was wrong or not, because the researcher hoped students became more confident in their own thinking in learning mathematics. And it worked, because after that, the researcher saw that students were more confident and brave to propose their own thinking. At the question 1f, the researcher found that some students (four groups) had improved in giving correct reasons to a specific situation. But in contrast, at the question 1g, the researcher found that students had a problem when they were asked to reason abstractly, because there were only two groups which gave correct reasons. And this happened again on question 1h, where no group gave correct answers. This evidence tells that most students did not
yet know how to give a general answer, without reference to any specific situation. However, the researcher was satisfied with students at the first section, because the researcher observed that students became more confident, enthusiastic and engaged in their learning activities.

In the DGS section, the researcher tried to emphasize what students learned from the first section. The researcher observed that students were excited playing and learning through Geogebra, even though they experienced some difficulties to use Geogebra tools in the beginning. The researcher saw that students did not really have a problem to do tasks 1 till 6, because the researcher guided them by showing and telling them what tools they needed in order to construct the pictures. Also the researcher was asking questions which directed students to correct conclusions. However, at the question 7, students did not recognize that what they just constructed was a block, probably, because the picture was still not clear as a block. This evidence shows that students did not succeed using their intuition skill at this question. After they did the task 8, they did recognize what they just constructed: a block. The researcher expected that after doing the tasks in the first section and the second section, students will better understand about corner points, edges, parallel lines, intersecting lines, crossing lines, which will be used to learn about the concept of angle in the second meeting.

6.7.2 The Second meeting
In the second meeting the students were still grouped in 6 groups of 6 students in each group, but the researcher changed members of each group because the researcher wanted every student to have an opportunity to collaborate with many students in varying groups. There were also two sections in the second meeting, which were a section without computer use, and a section with computer use.

6.7.2.1 Section without computer use
In this section the researcher was starting the class by giving some questions about what they had learned in the first meeting to make students aware of what they already
knew. After that the researcher started to distribute lesson materials of the first section. The results of the first section are shown below.

1. *Take two small and short sticks, then join their end point and also give a name A, B, and C to every end of the sticks like in the picture below:*

![Diagram of sticks forming an angle]

**a. What are the points A, B, and C for in the picture above?**

The aim of this question is: students will be able to understand that an angle is formed by two lines, and the expected answer is: to name sticks as segment line AB and segment line AC.

In this question, all groups gave correct answers, writing that the function of A, B, C is to create a line, to make an angle, and to recognize points of an angle. It means that students understood the function of naming three points of an angle.

**b. How do you call the figure formed by both sticks above?**

The aim of this question is: students will be able to recognize an angle shape, and the expected answer is: an angle BAC or an angle CAB or just an angle.

In this question all groups could give correct answers. It means that students did not find it difficult to recognize the shape of an angle.

**c. If every stick represents a segment line that is related to the picture, then what is the reason those segments can form an angle?**
The aim of this question is: students will be able to understand that an angle can be formed by two different lines that are not parallel, and the expected answer is: because those lines are not parallel to each other.

In this question, there are three groups that gave correct answers, and three other groups did not give correct answers. One of the incorrect answers is: because having an angle, which is a tautology.

d. What are the important elements of an angle?

The aim of this question is: students will be able to know what the important elements of an angle are, and the expected answer is: the important elements of an angle are (1) the corner point which is the intersecting point of two lines, (2) the legs of an angle which are the lines that are intersecting each other, (3) the name of every end point of an angle.

In this question, most groups just wrote that the important elements of an angle are points, lines, and an angle shape. Actually what the students wrote is not exactly what the researcher expected. The researcher supposes that students just did not know yet the name of each element.

2. Look at the picture below:

![Diagram](image)

a. How many angles are there that you can identify from the picture above?
The aim of this question is: students will be able to recognize many angles that are put at one common corner point, and some possibilities of expected answers are: 3 angles, 4 angles, or 6 angles in that picture (external angles are not yet expected). In this question there are two groups that answered 3 angles, from which the researcher concludes that the students just could recognize the three small angles which are angle EAB, angle BAC, and angle CAD. There are two groups that answered 4 angles, but they gave different explanations in their answers. The first one wrote there are three acute angles and one obtuse angle, so there are 4 angles. The researcher tries to understand this answer as meaning that the students recognized the three angles which are angle EAD, angle BAC, and angle CAD as the acute angles, and angle EAD as an obtuse angle, even though angle EAD is not an obtuse angle in the picture above. The second group wrote: angle AE, AB, AC, AD there are 4 angles. It shows that they were still not able to distinguish between angles and segment lines. The two other groups answered that there are 5 angles and there are 9 angles. Both answers actually are difficult to interpret, because the possibilities of acceptable answers are 3 angles, 4 angles, and 6 angles.

b. Can you recognize which one of these angles is the biggest one? Please give your reason.

The aim of this question is: students will be able to recognize an angle with big size, and the expected answer is: the biggest angle is angle EAD or angle DAE because angle EAD is composed of other angles.

In this question, there are only two groups answering that the big angle is angle EAD with different reasons. The first answer is angle EAD because it is an obtuse angle so creating a big angle. Even though the answer is correct, it shows that the students did not know yet what the definition of obtuse angle is, because angle EAD in the picture is an acute angle. The second answer is angle EAD because it has a slope of almost 90 degree. The researcher thinks that the second answer has a better reason, and the students could recognize the big angle by seeing its slope size. The other groups gave incorrect answers and unrelated reasons. It shows that some students still found it
difficult to recognize angles which have a common corner point, and they only could recognize “simple angles” like angle EAB, but they could not recognize angle EAD which is composed by all smaller angles.

3. Look at the picture below:

![Source: http://jepretanku.files.wordpress.com/2008/03/rumoh-aceh-traditional-house1.jpg](http://jepretanku.files.wordpress.com/2008/03/rumoh-aceh-traditional-house1.jpg)

*a. Which parts of the house are forming angles? Please give your reason.*

The aim of this question is: students will be able to recognize any shapes in their real life that forms an angle shape, and one of possible answer is: the roof of the house because both sides of the roof are not parallel and meeting at one corner point.

In this question, all groups mentioned the roof of the house which forms an angle, with different reasons which are because its shape looks like an angle (three groups), because it forms a triangle (two groups), and because it has two sides which meet at 1 common point (two groups). It shows that students could recognize an angle in a real life context.

*b. Which parts of the house are not forming angles? Please give your reason.*

The aim of this question is: students will be able to recognize any shapes in their real life that do not form an angle shape, and one of the possible answers is: the pillars of the house because all pillars of the house are parallel and not meeting anywhere.

Three groups answered: the pillars of the house do not form an angle, with reason: because all pillars are perpendicular to the floor and do not meet each other at any one
common point. Two groups wrote the garden is not forming an angle with the reason it
does not show an angle. And one group did not give any answer. It shows that students
found it much easier to recognize a shape of an angle than elements that do not form an
angle.

6.7.2.2 Section with computer use

In this section, the groups were changing again and there were six students in each
group. What students did in this section is shown below.

1. **Draw a picture like below**

![Diagram of unparallel segment lines](image)

The aim of this task is that students can recognize a picture of unparallel segment lines.
Using Geogebra, students did not find it difficult to draw a picture like above. After that
the researcher asked a question to students, are they parallel or not? The students
answered, they obviously do not look parallel.

2. **Construct the angle between those two segment lines above.**

In this task the researcher hoped that students learn how to make an angle from two
unparallel-segment lines which were not intersecting yet, by translating one segment to
another without changing their slopes. Even though by extending both lines, an angle
can also be created, the researcher only wants students to do a similar action like they did with the two sticks in the first section.

In this question, students were asked to use the Geogebra move tool to connect an end point of a segment line to an end point of another segment line. To do that, the researcher asked them to choose which one of segment lines will move and which one will stay motionless. After that, by using the move tool, students could put an end point of the moving segment line to one end point of the other segment line.

3. How many possibilities of an angle picture can you construct between them?

After students could create an angle by translating the segment lines one to another, the researcher asked students a question, can we create an angle between the two segment lines without translating them like we did before? Students got confused by this question, because they already stuck on their mind that the segment lines could only be moved to create an angle. The researcher asked another question, can we extend a segment line to be a line? Students answered yes we can. After students realized that a segment line could extend to be a line, the researcher asked students to extend each of the segment lines (The researcher taught students about a line, a segment line, a ray in the introduction of Geogebra, in which they learned about all those things through using tools). After that, the researcher asked students a question: look at the picture you just drew. Do the extended lines create an angle? Students answered: yes, but not only one angle is created here, there are four angles we see. The researcher responded by saying: yes, you’re right. The researcher hoped students learned and realized that there were two ways to construct angle shapes from two given segment lines, which were by translating them and by extending them.

4. Do they have the same size?

The students were asked to investigate whether the two ways of creating angles from two segment lines gives the same size of angle. The researcher asked them to use a tool that can measure a size of angle to their own angle pictures. This question took a lot of
time, because students found it difficult to use the tool for the first time. But after students finished working on measuring the angles, they could conclude that both ways gave the same results.

5. Draw pictures like below

Students did not find difficult to draw all those pictures, because they already got used to draw by using Geogebra tools.

6. How many angles for each picture above are there?

After students drew pictures like above, the researcher asked them a question, how many angles are there in each picture? (In this question, the researcher was still not expecting the exterior angles) All students could answer well for the simple one picture that only shows an angle. But for the two other pictures, there were many answers that students gave. This question was very tough for them. The researcher helped them to recognize how many angles in the middle picture, which there are three angles, and left to them the complicated lower picture to investigate. Finally, students were able to recognize how many angles are in the complicated one, six angles. The researcher
hoped that students learned from this question how to recognize angles that are formed by many segment lines that meet at a common point.

7. *Can you see a pattern of those numbers of angles?*

In this question, students were asked to see whether there is a pattern or not from the picture above. Students found it really hard to see the pattern by themselves. Therefore the researcher gave questions one by one to help students seeing the pattern. Firstly, the researcher asked a question, look at the first picture. How many segment lines meet at a common point? Students answered, there are two segment lines. Then the next question, how many angles do you recognize? They answered, only one angle. The researcher asked them to write down what they just answered to each question, which is if two segment lines meet at a common point, then there is only one angle recognized. The researcher went on to the next pictures. Even though they already wrote what they answered to each question, which were 2 segment lines --> 1 angle, 3 segment lines --> 3 angles, 4 segment lines --> 6 angles, they still could not see the pattern. Actually, the pattern can be seen like this: 1 angle --- >3 angles (+2); 3 angles --> 6 angles (+3); 6 angles --- >10 angles (+4); etc. The researcher understood that students at this level could not see a pattern like that. The researcher finally gave them the formula, which is total angles = (n-1).n/2, where n is the total number of segment lines. The researcher hoped that students trained their intuition skill in trying to recognize the pattern of angles which were formed by many segment lines meeting at a common point.

8. *Can you guess how many angles exist if there are 5 segment lines meeting at one common point?*

After they got the formula, they were able to answer this question, which is 10 angles. The researcher asked them to draw a picture of five segment lines meeting at a common point, and asked them to see whether there are really 10 angles or not. After they were doing what the researcher asked, they said that yes, it’s true. What the
researcher hoped is that students learned from this question how they could combine their skills in thinking by seeing and by using a formula. However, the researcher could not check from student’s answers if this question had this effect.

6.7.2.3 Conclusions of the second meeting

In the pen-and-paper section, the researcher found that students understood the function of naming points of an angle, and they also could recognize a shape of an angle. However, at the question 1c, some students (three groups) could not give correct answers why two segment lines (representing of two sticks) can form an angle shape. This evidence tells that probably the students could not use what they learned in the first meeting to answer this question. The researcher also found that most students could recognize an angle, but they did not know the name of its elements. To overcome this problem, the researcher gave an explanation about the name of elements of an angle, at the end of the first section. At the question 2a, the researcher found that some students found it difficult to determine the number of angles from a picture that has many segment lines with a common corner point. They only recognized an angle which was composed of two segments lines which close to each other, but they did not recognize an angle which had some segment lines between its legs. Comparing students’ answers to questions 3a and 3b, the researcher concludes that most of the students found it much easier to recognize examples of angles rather than non-examples.

In the DGS section, the researcher tried to emphasize what students learned from the first section. Before the researcher gave some hints, students did not realize that an angle can be created by extending two segment lines which are not parallel on the same plane. At the question 6, students still found it difficult determine the number of angles from a picture which has more than two segment lines with a common corner point, but after the researcher gave them some help, then they could recognize the angles. Actually, at the question 7, the researcher expected that students would be able to see the pattern in the numbers of angles, but they could not. The researcher concludes that question 7 was really tough for them, especially at their ages.
6.7.3 The third meeting

In the third meeting, the researcher used a new strategy to make discussion between students in groups more lively by grouping the students in smaller groups, 3 students in each group. This strategy was used because the researcher learned from the two previous meetings where students did not have a good discussion among themselves. Therefore in the third meeting there were 12 groups in the class instead of 6 groups. And the researcher saw that it worked to encourage students to be more active in their discussions. The sections were still the same as the previous meetings, which were a section without computer use and a section with computer use. The results of each section are shown below.

6.7.3.1 Section without computer use

As usual the researcher started the class by giving some questions which were related to topics of the previous meetings to make students aware of what they already knew before going to the next steps. In this section the students were asked to discuss and to answer some questions in their own groups.

1. Draw a circle with a certain diameter that is appropriate to your paper like in the picture below:
a. Do you remember how many degrees is one full rotation of a circle?

The aim of this question is: students will remember the degrees of one full rotation of a circle, and the expected answer: $360^\circ$.

In this question, all groups gave the correct answer, which is $360^\circ$. It shows that all students still remembered the size of one full rotation.

b. Please give your reason why AOB can be regarded as an angle.

The aim of this question is: students will be able to recognize a straight angle, and the expected answer: AOB is an angle, which is a straight angle. It is considered as an angle because it has two legs (AO and OB) and one central corner point (O).

In this question, there are many reasons that students gave. There are three reasons which are understandable, which means the researcher could interpret what students wrote, but the other reasons are not interpretable. However most of the reasons are not correct. It shows that students could not apply their knowledge of angle elements in this situation (angle of $180^\circ$ degrees). One example of reasons that is understandable is: because when point A and point B are connected to point O they are creating an angle. The researcher thinks that the students who gave this reason recognized angle AOB formed by two segment lines AO and BO. One example of reasons that is not interpretable: shaping an acute angle. The researcher considers that the students who gave this reason did not understand the question.

c. How big is the size of angle AOB? Do you need a tool for measuring the angle AOB? Or can you simply use your intuition to get the degree of the angle?

The aim of this question is: students will be able to know the size of a half of a circle, and the expected answer is: No, I don’t need a tool to measure the angle AOB, because I can simply use my intuition by dividing one full rotation by 2, so the angle AOB is $180^\circ$.

In this question almost all groups gave the correct answer which is $180^\circ$, and only two groups gave an incorrect answer, writing $360^\circ$. Most of the groups did not use a tool to
know the size of angle AOB, but there is only one group that did it by using a protractor. It shows that most students did not really find difficult to answer this question.

d. Can the angle AOB be called as a straight angle? Give your reason.
The aim of this question is: students will be able to understand that a straight angle can be represented by any straight line, and the expected answer is: Yes, it can, because the angle AOB is lying on the diameter AB where diameter AB is a straight line.
In this question, all groups gave the same answer which is: yes, it can be called a straight line, and they also gave similar reasons like: because it is a line and it is passes through some points. The researcher thinks that the students were able to recognize that angle AOB can be called as a straight angle.

2. Look at the picture below:

a. Write down three angles that can be formed by those points on the lines that you can define.
The aim of this question is: students will be able to recognize angles that are formed by any point lying on a straight line, and some possibilities of answers are: angle ABC, angle BCD, and angle CED.
In this question there are four groups giving incorrect answers, and the other groups gave the correct answers. Most of the correct answers just mentioned straight angles, but there is one group also mentioned null angle DCE in the answer. One of the incorrect answers students gave is straight angle, obtuse angle, and right angle, from which the researcher concludes that these students did not understand the question.
The other incorrect answers are similar because the students wrote an angle like they write a segment line, for examples they wrote angle AB, angle BC, and DE. It shows that students still had a problem in naming an angle in an appropriate way.

b. *Please without using a protractor, write down the size of each angle you mentioned in the previous question.*

The aim of this question is: students will be able to compare between zero angle and $180^0$ angle, and the expected answer: angle ABC = $180^0$, angle BCD = $180^0$, and angle CED = $0^0$.

In this question, there are only two groups giving the correct answers, and the rest of the groups gave incorrect answers. Most mistakes that students made are that the students thought that there were right angles, acute angles, and obtuse angles in their answers, which is not correct, because angles that can be formed in the picture above are only $0^0$ and $180^0$. It shows that students had difficulty indentifying straight angles, despite the good results of questions 1a, c and d, and in agreement with the difficulties found with 1b.

c. *Is angle ABC bigger than angle BCD? Give your reason.*

The aim of this question is: students will be able to understand that an angle is not depending on the size of their legs, and the expected answer: angle ABC is the same as angle BCD, because both of them are equal to $180^0$.

In this question, there are only two groups giving the correct answer, and the other groups gave incorrect answers. The interesting thing about the incorrect answers is the students’ reason why most of students considered angle ABC as bigger than angle BCD: because the angle ABC is longer than angle BCD in length. It shows that there was a misconception about the size of angles in students’ mind.
3. Look at the pictures below:

a. Without using a protractor, please, try to answer the question whether angle EDF is bigger than angle MKL? Give your reason.

The aim of this question is: students will be able to recognize a small difference in size between two angles, and the expected answer: angle EDF is smaller than angle LKM, because angle EDF looks sharper than angle LKM.

In this question, there are four groups giving the correct answer, and the other groups gave incorrect answers. The students who gave the correct answer gave reasons that angle EDF is smaller than angle MKL, because angle EDF tends to the right, and angle MKL is bigger than angle EDF, because KM looks higher than DF. It shows that some students had a good intuition to answer this question. However, there were still other students having a problem in their intuition to answer this question. Students who gave incorrect answer were mostly judging that angle EDF is bigger than angle MKL, because angle EDF has sides longer than sides of angle MKL.

b. With your intuition, please try to guess the degrees of each angle in the picture above? Please give your reason.

The aim of this question is: students will be able to guess degrees of some angles, and the expected answer is: angle BAC = 90° (because angle BAC looks a half of straight angle), angle EDF = 45° (because angle EDF looks a half of angle BAC), angle LKM = 60° (because angle LKM is a bit bigger than angle EDF), and angle POQ = 30° (because angle POQ looks a half of angle LKM).

In this question, there is no group which gave all correct answers to each angle. The researcher found some groups guessing that angle BAC = 180°, angle FDE = 120°, angle
MKL = 100°, and angle POQ = 90°. It shows that all students still had problems in estimating the size of angles by seeing the pictures only, and also they did not understand yet about straight angle, acute angle, right angle, and obtuse angle. Actually, the researcher expected students were able to answer this question because at the question 2c, they already could recognize the size of the angle of a half of a circle, and they should have used the analogy of thinking to answer this question.

6.7.3.2 Section with computer use
After they finished with the first section, students continued to work with computers. In this section there were still only six groups of 6 students in each group. What students did in this section is described below.

1. Draw a picture like below

In this task, all groups could make it without facing a lot problems. After they drew the picture like above, the researcher asked them to find all angle shapes in the picture. The first time, students just saw only one angle that they recognized, which was an obtuse angle AOB, because they did not recognize yet the other area of the circle beside the obtuse angle AOB as an angle. But after the researcher gave a little explanation about
that, they seemed to understand that there were two angle shapes in the picture, which were the big angle AOB and the small angle AOB.

2. *Measure the small angle AOB and the big angle AOB. Calculate the sum of them.*
After students recognized there were two angles in the picture, the researcher asked them to measure the size of each angle. They did not find it difficult to use a tool for measuring an angle in Geogebra. After that, they were asked to calculate the sum of the two angles. All students could do this task well, and they found the sum of those angles is $360^\circ$.

3. *Drag point B around the circle. Investigate the changes of those angles and find out if their sum changes or stays the same.*
After the students were able to recognize and to calculate the two angles in the picture, the researcher asked them to change the size of angle AOB by dragging point A or point B. As point A or point B was moved, Geogebra displayed automatically the new size of angle AOB. Then the researcher asked them to write down the new size of those angles, and asked them to calculate again. The researcher asked them to do this action three times, and asked them to make their own conclusion about what they had done. Even though the students had known by memorizing that the sum of those angles is always $360^\circ$, but the researcher hoped that by this activity students could better understand that one full rotation of a circle is $360^\circ$, because they had an experience of how the sizes of both angles changed when they were dragging points around the circle by using Geogebra.

4. *When does the condition happen, where the small angle AOB and the big angle AOB have the same size?*
The researcher asked students to investigate when both angles have the same size. Without using Geogebra, some students answered that each angle must be $180^\circ$ because the total must be $360^\circ$. Even though some students were able to answer this
question intuitively, the researcher still asked them to play with Geogebra to find a picture where both angles are the same in size. After trying out moving point A or point B, students found the condition, where point A, point O, and point B were on a diameter of the circle.

5. When does the small angle $\angle AOB$ reach the smallest size?
   In this question, the students did not find it difficult to find out the solution, because by Geogebra they could easily drag point A or point B to get the condition where the small angle $\angle AOB$ reached size $0^\circ$. By only dragging one of those points, the researcher hoped that students could realize that $0^\circ$ degree appeared when point A and point B are together at the same place.

6. Draw a picture like below.

   ![Geogebra screenshot](image.png)

   In this task, all groups could do it well without having problems. After they drew the picture, the researcher asked them to recognize angles in it.
7. *Measure angle ABC, angle ABD, and angle BCD. Are they the same in size? Why?*

Even though by using Geogebra students could easily measure all angle sizes, they found it a bit difficult to give the reason why all the angles had the same size. The researcher guided them to see carefully the similarity of those angles, which they are all on the same lines and they are straight angles, and the corner point is in between the other angle points. After this task was done, the researcher hoped that students were able to understand the reason for the equality of these angles.

8. *Measure angle ACB, angle BCA, and angle DBC. Are they the same in size? Why?*

In this question, by using Geogebra, students could easily find out that the size of these angles is $0^\circ$. Like with question 7 the students could not give their own reasons, so the researcher guided students to understand why all those angles are the same size, which is because they all are on the same lines, and the corner point is not in between the other angle points. The researcher expected that students were able to understand the reasons why those angles had the same size after they did this task.

**6.7.3.3 Conclusions of the third meeting**

In the pen-and-paper section, the researcher found that most students could not explain why AOB (the diameter of a circle with centre O) can be regarded as an angle AOB. The researcher concludes that students did not yet recognize AO and BO as legs of the angle, and O as the corner point of the angle, which means that students found it difficult to recognize a straight angle as an angle. However, they did not have any problem to determine the size of angle AOB, and most of the students did not use a protractor, because they simply divided $360^\circ$ by 2. Students also could recognize angle AOB as a straight angle, because they see AOB obviously as a diameter of a circle, which could also be representing a line. However, most students found it difficult to recognize a straight angle at question 2, probably, because they did not see it as a half of circle. Most of students considered angle ABC as bigger than angle BCD by comparing the length of ABC and the length of BCD, while both angles should be the same size ($180^\circ$).
At the question 3a, some students used their intuition skill well and gave a good reason in their answers. However, other students still judged the size of an angle by the length of its legs. At the question 3b, the researcher found that students had difficulty estimating the size of an angle just by seeing.

In the DGS section, overall students did not really have problems to do the tasks. The researcher observed that students could find the difference between a straight angle and a null angle, which they did not get it yet in the pen-and-paper section, because using Geogebra students could easily experiment with creation of null angles.

6.7.4 The fourth meeting

In the fourth meeting, the researcher still grouped students within 12 groups like in the third meeting, and members of each group had been changed like the researcher did in the second meeting and third meeting. In this meeting also there were still two sections like in the previous meetings, which were a section without computer use and a section with computer use.

6.7.4.1 Section without computer use

Like the previous meetings, at the beginning of the class the researcher was asking the students some questions about what they just learned in the previous meetings. The students seemed like they got used to the researcher’s teaching style, so they were ready when the researcher asked them questions at the beginning of the class. This was shown by their enthusiasm to answer the questions, and a lot of them could answer those questions well. After that the students were starting again to work in their own groups. The results of their work without computer use are shown below.
1. Look at the picture below:

Is angle BAC bigger than angle DAE? Please give your reason.

The aim of this question is: students will understand that if two angles have their legs on the same two lines then they are the same angle, and the expected answer: angle BAC is neither bigger nor smaller than angle DAE, because their legs are lying on the same lines.

In this question, there are only three groups which answered angle BAC is not bigger than angle DAE, with reasons because they have the same corner point, and because their angle shapes are the same. Meanwhile the other groups answered angle BAC is bigger than angle DAE, with reasons because angle DAE is inside of angle BAC, and because angle BAC has legs longer than legs of angle DAE. It shows that some students still considered that the size of an angle depends on the size of its legs.
2. Look at the pictures below:

   ![Diagram](image1)

   ![Diagram](image2)

   ![Diagram](image3)

   ![Diagram](image4)

   a. **Before using a protractor, please estimate every angle by using your intuition.**

   The aim of this question is: students will be able to estimate sizes of angles by using their intuition only, and the expected answer: angle BAC = 120°, angle HGJ = 270°, angle DFE = 280°, and angle KLM = 225°, with expected accuracy roughly ± 10°.

   In this question, there are many different guessing answers that students gave to each angle. Even though, while displaying this question, the researcher asked students to focus and to estimate the size of angles with the color area, the researcher still found some students misunderstood reading the picture of angle HGJ, because they answered angle HGJ is 90°, which should be 270° because the picture asked the size of big angle HGJ. And this happened to angle DFE and angle KLM also. It shows that students just considered angle shapes as only acute or obtuse angles.

   b. **By using a protractor, find out all the degrees of the angles.**

   The aim of this question is: students will be able to measure angles by using a protractor, and the expected answer: angle BAC = 120°, angle HGJ = 270°, angle DFE = 280°, and angle KLM = 225°, with expected accuracy roughly ± 5°.

   In this question, there is no one group giving all correct answers to each angle. Only angle BAC was answered well by some students, but they misunderstood angles HGJ, angle DFE, and angle KLM like in the previous question. Students also made some
incorrect measurements of some angles, because even though they misunderstood reading the picture, they should give an accurate number for each angle. For example, they measured angle DFE as $65^0$, which should be $60^0$ if they misunderstood the angle picture. It shows that some students also had problems with measuring using a protractor.

c. Did you find difficult to find out all those angles by using a protractor? What did you do to overcome the difficulty? Please give your explanation.

The aim of this question is: students will be able to evaluate the problems they face using a protractor, and the expected answer: the problem is when measuring angles that are more than $180^0$. To overcome the problem, first of all, measure the small one, then after that subtract it from $360^0$, because the sum of the big one and the small one is $360^0$.

In this question, all students wrote they had difficulty using a protractor to measure the angles, but they did not mention in a specific way how they tried to overcome the problem. Actually, during the students’ activity, the researcher was walking around the class and giving some hints to answer the questions, but the researcher did not disturb students’ concentration by intervening too much in their discussions, because the researcher wanted them to answer by their own attempts even though their answers were not correct yet. By the researcher’s observation, the problem which students faced in using a protractor was that they were a bit confused while reading numbers on a protractor, because for one size of an angle on a protractor there are two numbers, for example, the size $30^0$ and the size $150^0$ are at the same place. Also the numbers on a protractor are a bit small, so some students made incorrect measurements because of this. To overcome students’ difficulty in using a protractor, the researcher gave an explanation of how to use one after they finished question 2c. In this way, the researcher hoped students would understand so that they could answer the next question 3b.
3. An angle between $0^\circ$ and $90^\circ$ is called an acute angle, an angle between $90^\circ$ and $180^\circ$ is called an obtuse angle, an angle of $90^\circ$ is called a right angle, and an angle of $180^\circ$ is called a straight angle.

Look at the pictures below:

a. Use your intuition to classify all angles above in their categories.

The aim of this question is: students will be able to classify angles into their categories using intuition, and the expected answer is: the group of acute angles: angle BAC and angle NMO; the group of obtuse angles: angle EDF and angle HGI; the group of right angles: only angle QPR; the group of straight angles: only angle KJL.

In this question, all groups gave the correct answers to each angle. It shows students had no problem to recognize angles in angle categories, and they got better at estimating an angle after they learned from their mistakes in the previous questions, which were question 2a and question 2b. It shows also that classifying is easier than estimating and measuring, because students did not need to mention a specific number to answer this question.
b. *Use a protractor to classify all angles above in their categories.*

The aim of this question is: students will be able to classify angles into their categories using a protractor, and the expected answer is: the group of acute angles: angle BAC, and angle NMO. The group of obtuse angles: angle EDF, and angle HGI. The group of right angles: only angle QPR. The group of straight angles: only angle KJL. In this question, all groups gave the correct answers. The researcher thinks that students had no problem again in classifying angles by using a protractor, because after students were already answering question 2b, the researcher gave some explanation how to use a protractor appropriately.

c. *Is there any different result between those two ways? Give your explanation.*

The aim of this question is: students will be able to compare their results between using intuition and using a protractor, and the expected answer is: there are differences between those two ways of finding the sizes of angles, because sometimes intuition leads to mistakes and measuring sometimes leads to errors.

In this question, most of the groups just wrote similar words, something like: the difference is the first one using intuition and the second one using a protractor, because it could be that they did not see any different result of the classification of the angles in angle categories. But there was one group which wrote additional words like: there is some difference in the size of angles found when using intuition and using a protractor. This shows that the students had no problem in understanding angle categories.

6.7.4.2 *Section with computer use*

Like the previous meetings, in this section students were still in 6 big groups. What students did in this section is described below.
1. **Draw a picture like below**

![Geogebra interface](image)

Students did not find difficult to do this task, because they had become familiar with Geogebra tools.

2. **Measure angle BAC.**

Students could also easily find the size of angle BAC using Geogebra tools.
3. Extend segment line AB, and AC like in the picture below

In this task also students did well drawing the picture.

4. *Measure angle DAE. Compare with angle BAC. Do they have different size? Why?*

Students found that angle DAE and angle ABC had the same size, but the reason was not easy for them. To help students to find the reason, the researcher asked them to recognize the similarity of each leg of those angles and the corner of each angle by asking some questions. First of all, the researcher asked a question: are leg AC and leg AE on the same line? Students said: yes, they are. After that the researcher asked the next question: what about leg AB and leg AD? Students said: they are also. And after that the researcher asked another question: do angle DAE and angle BAC have the same corner point? Students said: yes, they do. The researcher said that all those facts are the reasons why angle DAE and angle BAC are the same. The researcher hoped that finally they understood the reason why both angles are the same size.
5. **Draw a picture like below.**

![Image of a geometric figure]

Students did not find it difficult to draw the picture.

6. **Measure angle GHI, angle GIH, and angle HGI.**

Some mistakes in measuring those angles happened when the students did not use a tool for finding the intersection of two objects, which means the points that students made were not exactly at the intersection of two lines; therefore, some students got the wrong measurements. After the researcher helped them to fix the picture they made, students were able to find the sizes of all the angles by using Geogebra tools. The researcher asked them to calculate the sum of those angles, which resulted in a sum of $180^\circ$.

7. **Drag any point except point G, H, and I. See what happens to the sum of angles GHI, GIH, and HGI.**

The researcher asked students to calculate again the sum of the angles after the position of each point had changed. Students were asked to perform the operation (dragging one of the points) three times. As a result they found that the sum of the three angles was always $180^\circ$. 
8. **What is your conclusion about what you have done?**

The researcher asked students a question: what is the shape of GHI? The students answered: a triangle. And the researcher asked another question: after you drag points of the triangle GHI to get many different shapes of triangles, what is your conclusion about the angles in a triangle? Students answered: the sum of them is $180^\circ$.

9. **Draw a picture like below**

![Diagram](image)

Students did not find it difficult to draw the picture.

10. **Triangle ABC above is called an obtuse triangle. Do you know the reason?**

The researcher asked students to measure all angles of the triangle. They found that there were two acute angles, and one obtuse angle. And after that, the researcher asked them, can you guess why the triangle ABC above is called an obtuse triangle? Some students answered: maybe because one of its angles is an obtuse angle. The researcher said: that is a correct reason.
11. *Please draw a right triangle and an acute triangle.*

In this task, students did not find it difficult to draw the two triangles with Geogebra. What they learned was in a right triangle there is one right angle in it, and in an acute triangle all angles are acute angles.

**6.7.4.3 Conclusions of the fourth meeting**

In the pen-and-paper section, for question 1, the researcher still found that some students considered that the size of an angle is dependent on the length of its legs, even though from the previous meeting they had already answered similar problems. The researcher concludes that students could not use their experience to answer similar problems. The researcher also found that students had a problem in using a protractor to answer question 1b. To overcome this problem, the researcher explained how to use a protractor properly. On question 2a, the researcher found that students only considered the size of an angle which was less than $180^\circ$, even though in the third meeting they had learned that the size of an angle could be more than $180^\circ$. However, for question 3, the researcher found that students did not have a problem in using a protractor to answer this question, and they could classify angles into categories without any mistakes. The researcher concludes that classifying was easier for students than estimating and measuring.

In the DGS section, students did a small investigation on a problem similar to question 1 in the first section. After the researcher helped and guided students to investigate why angle $\angle DAE$ and angle $\angle BAC$ have the same size, students found that the size of an angle does not depend on the length of its legs. Students also found that the total of the three angles of a triangle is always $180^\circ$, and they found a reason why some triangles can be called obtuse triangles.
6.7.5 The fifth meeting

In this meeting, the researcher kept using a strategy that grouped students in small groups, so that there were 12 groups, each of which had 3 students. The researcher saw that the students became more confident and engaged in discussions in their own group after the groups became smaller. Like in the previous meetings, in this meeting there were also two sections, which were a section without computer use followed by a section with computer use. The results of the sections are described below.

6.7.5.1 Section without computer use

In this section, the researcher also began the class by asking some questions about what students had learned from the previous meetings. After that, the researcher started to distribute lesson materials to all groups and asked them to do the tasks that were displayed one by one through a projector. The students’ work in this section is shown below.

1. Look at the pictures below:

   ![Diagram](image)

   a. Without using a protractor, can you calculate angle DAB if angle CAD and angle CAB are known? If so, how would you do it?

   The aim of this question is: students will understand that angle DAB can be calculated by subtracting angle CAD from angle CAB, and the expected answer: yes, angle DAB can be calculated, because angle DAB is a part of angle CAB and angle CAD is also a part of angle CAB, so by subtracting angle CAD from angle CAB will lead to get angle DAB.

   In this question, only one group gave the correct answer, writing that angle CAB subtracted by angle CAD gives angle DAB, but it looked like they used a protractor to
answer this question, because in the answer the group wrote angle DAB = 85°, angle CAB = 120°, and angle CAD = 35°. Meanwhile the other groups gave incorrect answers. Most of them just wrote: "it can be done just by guessing", which means they only gave the size of angles without using analytical steps. It shows that most students were not able to invent without help that angle DAB is a subtraction part of angle CAB.

b. Without using a protractor, can you calculate angle GFE if angle GFH and angle HFE are known? If yes, how would you do it?

The aim of this question is: students will be able to understand that angle GFE can be calculated by adding angles GFH and angle HFE, and the expected answer: yes, angle GFE can be calculated, because angle GFE is composed of angle GFH and angle HFE, so by adding angle GFH and angle HFE we will get angle GFE.

In this question, there are six groups giving the correct answers. One of their answers was, "the size of angle GFH added to the size of angle HFE becomes the size of angle GFE". Meanwhile the other groups gave incorrect answers. By comparing the results of question 1b, the researcher finds that students were more able to recognize an angle as a total of two angles than an angle as a subtraction part of another angle. In other words, students found it more difficult when they dealt with subtraction than when they dealt with addition.

c. Please use a protractor to measure all the degrees of the angles above, and compare the results to your previous answers of the questions 1a, and 1b. Is there any difference between the results of the two ways? Why?

The aim of this question is: students will be able to compare their intuition skill and measuring skill, and the expected answer is: "The first one is subtraction of angles, meanwhile the second one is addition of angles."

In this question, there is only one group which gave the correct answer; the group wrote it as: angle DAB = 80°, angle CAB = 120°, and angle CAD = 40°; angle CAB is subtracted by angle CAD, then the result is angle DAB; or the other way around: angle DAB added to
angle CAD, then the result is angle CAB. Angle HFE = 40°, angle GFH = 30°, and angle GFE = 70°; angle GHF added to angle HFE, then the result is angle GFE or the other way around: angle GFE subtracted by angle GFH then the result is angle HFE.

There are two groups which wrote their measuring results of each angle, but then they only wrote the addition relationships between those angles: adding the two smaller angles gives the big angle.

The other groups just wrote their measurement results without writing the relationships between those angles. So in total, one group discovered subtraction of angles (see question 1a and 1 c), six groups discovered addition (question 1b) but only 3 of those could confirm this discovery by doing measurements (question 1c).

Comparing the answers of questions 1 b and 1 c, the researcher can conclude that students were more able to get and to understand a formula when they dealt with numbers than when they dealt with abstract things.

The two pictures and definitions below were given before students answer the question 2:

- Two angles that have their sum equal to 90° are called complementary angles of each other.
- Two angles that have their sum equal to 180° are called supplementary angles of each other.
2. **Look at the picture below:**

![Diagram](image)

*a. AB and CD are the segment lines intersecting at point E. Please write down angles that are supplementary angles to each other.*

The aim of this question is: students will be able to recognize supplementary angles from two intersecting lines, and the expected answer is: angle AEC together with angle CEB, angle CEB together with angle BED, angle BED together with angle DEA, and also angle DEA together with angle AEC.

In this question, there were five groups out of 12 giving correct answers, and the other groups gave incorrect answers. One of the incorrect answers which students gave is that they wrote angle DEB is a supplementary angle to angle DEB itself. It shows that some students could not recognize supplementary angles.

*b. Based on your intuition, are there any angles having the same degree? Give your argumentation.*

The aim of this question is: students will be able to recognize angles that have the same size from the intersection of two lines, and the expected answer: Yes there are some angles having the same degree, angle AEC must be the same as angle BED, because angle AEC + angle CEB = 180°, meanwhile angle CEB + angle BED = 180° as well. Another pair of equal angles are angle CEB and angle DEA, because angle CEB + angle BED = 180°, and angle BED + angle DEA = 180° as well.
In this question, there were four groups giving correct answers, but they gave different reasons that are acceptable in the researcher’s opinion. Their reasons were: "because the angles have the same shape" (1 group), "because the angles have the same size" (3 groups). Meanwhile the other groups gave incorrect answers. One of the incorrect answers is that the students wrote angle ABC has equal size to angle ABD, because they have size $180^0$. A common mistake that students made is that they tried using the rule of question 2a to answer question 2b. It means that a lot of students found it difficult to understand and to recognize angles which have the same size formed by two intersecting lines.

3. **Look at the picture below:**

   *AB and CD are parallel segment lines, and EF is the segment line intersecting them at points G and H.*

   ![Diagram](image.png)

   **a. Based on your intuition, identify three pairs of angles that have the same degrees. Give your argumentation.**

   The aim of this question is: students will be able to recognize angles that have the same size from a pair of two parallel lines intersected by another unparallel line, and one of the possible answers is: angle AHE is the same as angle CGH, because line CD is a translated line of line AB so all angles shaped by intersecting line AB to EF will have the same size as all angles shaped by intersecting line CD to EF. Therefore, two other
examples of angles which have the same size are angle AHG = angle CGF, and angle EHB = angle HGD.

In this question, there were five groups out of 12 giving correct answers with common reasons given: because the angles have the same size, or because the angles are parallel. The other groups gave incorrect answers, most of them making wrong pairs of the angles. For example, they wrote angle FGC has the same size as angle GHB. It could happen because the students were not really careful in recognizing the angles which have the same size. It shows that some students found it difficult to recognize angles which have the same size as in the picture above.

b. If you are asked to find out all degrees of angles in the picture above, how many angles do you need minimally to find the other angles? Give your reason.

The aim of this question is: students will be able to understand that to find all unknown angles in the pictures they only need one angle known, and the expected answer: only one known angle is needed to find all unknown angles in the pictures, because by using the result of the previous question it shows that if one angle is known then other angles can be determined as well.

In this question, there are two groups that wrote they only needed 1 angle known to know all other angles. Three groups answered that they needed 2 angles known, four groups needed 3 angles known, and one group needed 4 angles to know all other angles. One group gave an unreadable answer, because the answer does not show the number of angles needed. One interesting answer is that one group wrote that they needed 8 angles, because there are 8 angles in the picture. It shows that a lot of students were not able to invent independently how to find out all sizes of angles in the picture above using only one known angle.

Before asking the question 3c, the researcher displayed the categories below.

Note: In the picture of question 3¹:

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¹ The Indonesian terms for pairs of related angles (in case of parallel lines intersected by a third line) are difficult, if not impossible, to translate. The English and Dutch terms do not convey the full range of meanings carried by the 6 different terms in Indonesian.
- *Sudut sehadap*\(^2\), an example of *sudut-sehadap* couple is angle DGF with angle BHG.
- *Sudut bertolak belakang*\(^3\), an example of *sudut-bertolak belakang* couple is angle BHE with angle AHG.
- *Sudut dalam berseberangan*\(^4\), an example of *sudut-dalam-beseberangan* couple is angle CDH with angle BHD.
- *Sudut dalam sepihak*\(^5\), an example of *sudut-dalam-sepihak* is angle AHG with angle CGH.
- *Sudut luar sepihak*\(^6\), an example of *sudut-luar-sepihak* couple is angle CGF with angle AHE.
- *Sudut luar beseberangan*\(^7\), an example of *sudut luar beseberangan* is angle CGF with angle BHE.

c. **For each category above, give another example.**

The aim of this question is: students will be able to recognize the relationship between angles, and the expected answer is: some possible answers are shown below.

- *Sudut sehadap*: angle FGC and angle GHA,
- *Sudut bertolak belakang*: angle FGC and angle DGH,
- *Sudut dalam berseberangan*: angle DGH and angle GHA,
- *Sudut dalam sepihak*: angle BHG and angle DGH,
- *Sudut luar sepihak*: angle DGF and angle BHE,
- *Sudut luar beseberangan*: angle AHE and angle DGF

In this question, no groups answered well. It shows that students still had difficulty to classify angle pairs into the given categories, because students not only should be careful to recognize each angle pair, but also should remember the name of each category. The researcher agrees that this question is hard for students, because the researcher remembered himself as a student in a junior high school found it difficult to understand all categories of angle relationships.

d. **Please summarize everything you have learned from the above questions as shortly as possible.**

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\(^2\) *Sudut sehadap* = angles which face the same direction. (=Corresponding angles)
\(^3\) *Sudut bertolak belakang* = angles which face the opposite direction. (=Opposite angles)
\(^4\) *Sudut dalam berseberangan* = Alternate interior angles
\(^5\) *Sudut dalam sepihak* = Interior angles of a transversal
\(^6\) *Sudut luar sepihak* angles = Exterior angles of a transversal
\(^7\) *Sudut luar beseberangan* = Alternate exterior angles
In this question, no group gave a summary. This shows that students had difficulty to summarize what they just learned. It might be that students did not get used to making summaries, especially in mathematics class.

6.7.5.2 Section with computer use

What students did in this section is described below.

1. Draw pictures like below

Students did not have a problem to draw the pictures.

2. Measure all the angles above. Then construct an angle that is formed by adding two of those angles above.

Students did not find it difficult to measure all angles, but they had difficulty in drawing the addition of the angles. But after the researcher helped them by showing the steps to draw it, then they were able to construct the addition of two angles. First of all, the researcher asked them to draw a new angle with the size of angle CAD, and its corner point at the corner point of angle EBF, and one of its legs on the leg FB of angle EBF.
After that, the researcher asked students to look and to measure the new angle constructed by two legs of those angles which are not on the same leg FB. Students found that the new angle had the same size as the total of angle CAD and angle EBF. After observing all the group work, the researcher saw that no group could construct the addition of two angles. The researcher hoped that students understood better the concept of addition of two angles after doing this task.

3. **Draw pictures like below**

![Diagram](image)

In this task students did well drawing the picture.

4. **Measure all the angles above. Then construct an angle that is formed by subtracting one of the above angles from the other.**

Like in question 2, students did not find it difficult to measure all angles using Geogebra, but they faced difficulties in constructing an angle by subtracting two angles. In this task, the researcher gave some help to enable students to draw by themselves, so finally they could do it. First of all, the researcher asked them to draw a new angle with the size of angle CAD, and its corner point at the corner point of angle EBF, and one of its legs on
the leg EB of angle EBF. After that, the researcher asked students to look and to measure the new angle between two legs of those angles which are not on the same leg EB. Students found the new angle had the same size as the subtraction of angle EBF from angle CAD. The researcher expected that after doing this task, students understood better the concept of subtraction of angles.

5. **Draw a picture like below**

Students drew a picture like in the picture above well.

6. **Measure all angles of the intersection lines. Drag point A and see what happens to the angles. Do the same thing to point B, C, and D.**

The researcher asked students to measure all angles and asked them to see which angles had the same size. Students were asked to change the position of point A three times, and were asked to write down what they found. They found that there were always two pairs of angles which had the same size, and the angles which had the same size were always on opposite sides.
7. **What is your conclusion about the intersection between two lines?**

   The researcher asked students a question, "what is the picture above?" The students answered: "intersection of two lines". The researcher continued to ask: "after you drag point A to different positions, what do you see in the picture?" The students answered: "the size of angles changing, but there are always two pairs of opposite angles which have the same size".

8. **Draw a picture like below**

   ![Diagram](image)

   The students did not find it difficult to draw the picture.

9. **Drag (=translate) line I to the point A then measure the angle at the point A. Please make a parallel line to I through point A.**

   Students did not find it difficult to do this task. The researcher asked them to look carefully at the picture they made, and asked them to write the size of the angle at point A.
10. Do the same things to point B. What is your conclusion on what you have drawn?

Students also did well drawing a line parallel to line $l$ at point B. After that, the researcher asked them to measure the angle at point B, and to compare the angle at point A. They found that both angles had the same size. The researcher hoped that students learned in this task that if two parallel lines are intersected by another line, then the angles at the points of intersection have the same size.

6.7.5.3 Conclusions of the fifth meeting

In the pen-and-paper section, by seeing students’ answers to question 1, the researcher concludes that students found it more difficult when they dealt with subtraction than when they dealt with addition of angles, and students were more able to obtain a formula when they dealt with numbers than when they dealt with abstract things. At the question 2a, the researcher found that most students did not really understand the definition of supplementary angles. Students also found difficult to understand some categories of relationships of angles which are formed by a pair of parallel lines intersected by another line. The researcher also found that students could not write a summary of what they just learned. The researcher concludes that making a summary and understanding a definition are difficult things for students in learning mathematics.

In the DGS section, the researcher helped and guided students to do the tasks. The researcher observed that students found and learned more about the concepts of subtraction and addition of angles at the task 1-4, which they found difficult to understand during the pen-and-paper section; students could see how opposite angles at the intersection of two lines have the same size; and also students could realize that a pair of parallel lines intersecting another line creates some relationships between angles which they learned in the pen-and-paper section.
6.7.6 Summary of the intervention findings\textsuperscript{8}

In the intervention findings, the following themes are recurring:

1. When do segment lines intersect?

2. Recognizing an angle, using angle attributes to reason that a figure is an angle, recognizing an angle even in difficult cases like: straight angles, composite angles, exterior angles.

3. Angle estimation / measuring / categorizing (acute / right / obtuse / straight)
   sub-theme: angle size is independent of leg size


Below the developments in each of the themes are summarized.

1. \textbf{When do lines intersect?}

   The theme question is first asked in meeting 1 (question 1d-h). Four out of six groups could recognize two different cases of non-intersecting lines (parallel and crossing) in a 3-dimensional picture (question 1f), but most of the groups could not generalize these observations into a rule (question 1g-h). An activity with Geogebra seemed to help (meeting 1, Geogebra task 5). In the next meeting, on paper, half of the groups were able to reason about why lines intersect (meeting 2, question 1c and question 3a-b).

2. \textbf{Recognizing an angle.}

   The theme of recognising an angle shape starts at meeting 2 (question 1). Students understand the need for labeling the three angle points (question 1a), they recognize an angle shape (question 1b) but they are not accurate about the important elements of an angle (question 1d). When they are asked to reason about whether something is an angle (meeting 3, question 1-2, the special case of a straight angle), they do not initially

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\textsuperscript{8} This section is contributed by Wolter Kaper, the supervisor of this research
use the angle elements, (like: one vertex and two legs) in their reasoning. The recognition of angles in a daily life context goes well (meeting 2, question 3). The recognition of composite angles is initially a problem (question 2), in the same meeting this same subject is tried again with use of Geogebra plus more explanation and a formula given by the teacher (meeting 2, Geogebra tasks 5-8), and, though finding the formula themselves was perhaps too much to ask, students made progress in counting - and therefore also recognizing - composite angles. Finally a problem about recognizing angles appeared in meeting 3 (Geogebra tasks 1-5) where angles of sizes larger than 180 degrees were introduced. At first everything went as expected, especially as long as the circle-picture was still there (Geogebra tasks 1-5). However at the next meeting, angles larger than 180 degrees were not recognized by students (meeting 4, question 2), possibly because the circle-pictures as used in meeting 3 were changed into other types of pictures. This problem did not get repaired, because no more activities were devoted to angles larger than 180 degrees. So we have evidence that most groups of students could recognize angles, even if they were straight angles or composed angles, but most students did not recognize angles larger than 180 degrees.

3. **Angle estimation, angle measuring, & angle categorizing (acute/ right/ obtuse/ straight)**

Finding the size of an angle is first done in meeting 2 with Geogebra (Geogebra task 4) and this results in ability to find an angle equality by measuring (Geogebra task 4). This measuring ability does not mean that students understand what we mean by the size of an angle. During the third meeting, various answers indicate that students consider the length of the angle's legs as important for the size of the angle (question 2c, q3a). This problem was expected from the literature (Clements and Battista, 1992) and during the fourth meeting two activities were planned to address this issue, one with pen and paper (meeting 4, question 1) and the other with Geogebra (Geogebra task 3). In the paper activity 9 out of 12 groups held on to their idea that leg-size is important. During the Geogebra activity, the teacher started a question-answer session that seemed to
convince the students (Geogebra task 4). It would be nice to measure some time later whether this result lasted!

Estimating an angle is first asked in meeting 3 (question 3) and goes on in meeting 4 (questions 2-3). In meeting three, 4 out of 12 groups were able to compare angles that differed by a small amount. In meeting 4, estimating angles initially did not go well, nor could students measure the given angles. The majority of the angles asked were bigger than 180 degrees and students did not recognize them, therefore could not measure nor estimate them (meeting 4, question 2). Categorizing angles into categories (acute / right/ obtuse/ straight) went well (question 3). We might conclude that categorizing is easier than estimating or measuring. However the reason might also be that all angles in this last exercise were smaller than 180 degrees (question 3). We conclude that students could categorize and measure angles smaller than 180 degrees by the end of meeting 4. Possibly they could also estimate such angles, but we are not sure, because the estimation activity was done with angles larger than 180 degrees mostly (question 2).

4. **Angle relations**

Angle relations were confined to meeting five, the last one. It was found that addition was handled more easily by the students than subtraction (meeting 5, question 1). Recognizing equality of two angles initially turned out problematic for 5 groups out of 12 in case of intersecting lines (opposing angles, question 2). The rule found about supplementary angles (question 2a) interfered and disturbed the recognition of equal opposing angles (question 2b). In the case of two parallel lines intersected by one non-parallel line, again 5 out of 12 groups could recognize equalities. In the session with Geogebra the same issues were addressed again, this time with more step-by-step instruction by the teacher and more experimentation by the students. It seemed to work, but as we have only the teacher/researcher’s notes, we lack an independent confirmation.
In general the data about the pen and paper sessions must be regarded as more reliable than the data about the Geogebra sessions, because in case of the pen and paper sessions written answers from all the groups were available, while for the Geogebra sessions (because students did mostly not write) no answers were collected and the researchers journal is the only source.

We conclude that for most of the themes (themes 1-3) we have evidence of progress. For some of the sub-themes (angles larger than 180 degrees) there was no progress. More lessons would be needed to have progress on all sub-themes. In as far as progress was seen, experimentation with Geogebra has played a role in solving problems in understanding that occurred (see themes 1-3 and possibly also 4). On some sub-themes (e.g. categorisation of angles, theme 3) progress happened in the paper and pencil part of the meeting. Often the paper and pencil part served well in finding out about students ideas, because they were obliged not only to discuss but also to agree and write down their answers. In all cases progress was connected to students being active: either in experimenting with the help of Geogebra, or in estimating, classifying and formulating answers on paper. These intervention findings do not show that the described teaching method gives better progress than other methods. But if by comparing test results this teaching method turns out to give more progress (which it did), than the above analysis shows that experimenting with Geogebra as well as student centered lessons are two likely causes of the difference.

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9 This ends the summary as contributed by Wolter Kaper
7. Conclusions and Discussion

7.1 Conclusions

In this section, I will try to conclude and to answer the main research question and the three sub research questions based on data analysis and findings.

7.1.2 The main research question: Is there any difference in students’ achievement between those who have been taught about angles according to an active learning approach using DGS and those who have been taught in the traditional way?

The analysis of the pretests shows that even though the experimental class got a higher score than the control class, they were not significantly different. It means that before the intervention to the experimental class, the two classes had the same level of knowledge in geometry. After I finished doing the intervention and the collaborative teacher had done her teaching of the control class, the posttest results show that the experimental class did better than the control class because there is a significant difference between their score-means. By all those findings I can say that the experimental class reached a better achievement than the control class did after the intervention, and that there is a significant difference between those classes’ achievement.

7.1.2 The first sub-research question: Does the active learning approach using DGS help motivate students to learn geometry?

According to the questionnaire results (multiple choice question), 94.3% of students answered that they were motivated by learning geometry through Geogebra, which shows that almost all students were motivated by the intervention. From the findings of the collaborative teacher’s interview, students were motivated by the intervention in which they got their first experience of learning mathematics through computers, especially
learning geometry through Geogebra. From all those findings I conclude that the active learning approach using DGS helps motivate students to learn geometry.

7.1.3 **The second sub-research question:** Do students feel that the active learning approach using DGS helps them to understand geometry?

Based on the findings of the questionnaire question 1, which was an open question, 80% of students said that learning through Geogebra helped them to understand geometry. Meanwhile based on the findings of the questionnaire question 3, which was a closed statement, 97.1% of students agreed that learning through Geogebra helped them to understand geometry. The findings of the three student interviews give information that learning through Geogebra helped them to understand geometry. By all those findings, I conclude that students think that the active learning approach using DGS helps them to understand geometry.

7.1.4 **The third sub-research question:** Does the active learning approach using DGS help students to improve their abilities of seeing, measuring, and reasoning in learning geometry?

Based on the findings of all meetings, I conclude that students gradually improved their abilities of seeing, measuring, and reasoning in learning geometry, even though students sometimes still made some mistakes in doing the tasks of each meeting. For example, for question 1e, I found that all students did not yet know how to give a reason in mathematics. At this stage, I just encouraged students to give their own reasons and arguments, no matter if it was wrong or not, because I hoped students would become more confident in their own thinking in learning mathematics. And it worked, because after that, I saw that students were more confident and brave to propose their own thinking. For question 1f, I found that some students (four groups) showed improvement in giving correct reasons to a specific situation. They also had been triggered to explore their intuition skill during the
intervention. In the first meeting, for question 7, students did not recognize what they just constructed was a block, probably, because the picture was still not clear as a block. This evidence shows that students did not succeed using their intuition skill at this question. However, since then students were triggered to use their intuition skill in learning geometry, and some students did well on this. For instance, in the third meeting, for question 3a, some students used their intuition skill well and gave a good reason in their answers. And they came to more understanding on how to measure an angle by using a protractor and by using Geogebra. For example, in the fourth meeting, I found that students had a problem in using a protractor to answer question 1b. To overcome this problem, I gave an explanation on how to use a protractor properly, and students showed improvement, which was on question 3, I found that students did not have a problem in using a protractor to answer the question, and they could classify angles into categories without any mistakes. Of course, there were many mistakes, that students made during learning activities. This could be because they had difficulty to maintain what they had just learned. However, overall I conclude that students showed gradual improvement in their abilities of seeing, measuring, and reasoning in learning mathematics, especially in learning the concept of angle in geometry.

7.2 Discussion

Motivation is one of the important things which a student should have in learning mathematics. However, to trigger and to maintain students’ motivation in learning mathematics is challenging for mathematics teachers, because most students, everywhere, consider mathematics a boring and difficult subject. An interesting case which I found in my research based on the collaborative teacher interview is: there is a student of the experimental class, Sindi, showing a significant change in her behavior in learning mathematics after my intervention was done. The collaborative teacher said that before my intervention, Sindi did not show her talent and ability in mathematics so much, but now she has become one of the active and diligent students in learning mathematics. From this finding, I can say that my intervention triggered Sindi’s motivation to learn mathematics. Even though to trigger students’ motivation is not easy, but to maintain students’
motivation is much harder. The collaborative teacher said that she was a bit afraid that she could not maintain her students’ motivation after my intervention, because she could not apply my kind of intervention to all her classes. Actually, she wanted to apply it, but she could not teach only one or two classes in this way while the other parallel classes get the traditional way.

This study has shown that the active learning approach using DGS is helpful for teacher and students. However, this research actually had some limitations, which were: (1.) the intervention was only conducted within a short period of time (5 meetings within 5 days, each meeting 2x45 minutes); (2.) The computers used in this researcher were very limited (only 6 computers for 36 students); (3.) The participants were junior high school students and they did not yet have any experience learning mathematics through computers (it was really exciting for them); (4.) the experimental class was quite big (36 students), which made class management a bit difficult.

All the limitations in my research resulted in a struggle to reach a better teaching situation. Therefore the results of this study can not be generalized to other situations. However, the result of this research can be used as a reference for mathematics teachers who want to try the active learning approach through DGS in their teaching. Therefore, for future research on active learning approaches using DGS, I suggest to investigate it for a longer series of lessons and with sufficient computers for the students. This kind of research could be useful to apply also at a senior high school level, where making mathematics more interesting to students might result in more students pursuing a career in mathematics, and also the geometry topics that students learn are more advanced.

As we know, nowadays teaching and learning through DGS is known among mathematics teachers, and also there has been a lot of research which was conducted to investigate about learning geometry through DGS. One of them is the research conducted by Sang Sook Choi-Koh (a professor of mathematics education from Korea), who investigated the geometric learning of a secondary school student during instruction, on the basis of the van
Hiele model, with dynamic geometry software as a tool (Choi-Koh, 1999). In his research, he examined the changes in the students’ learning according to the van Hiele levels of geometric thought for the geometric topics of right triangles, isosceles triangles, and equilateral triangles. The participant of his research was a student called Fred. However, this student had not taken geometry but had taken a computer course or had had experience with a computer at home, which means that he did not yet have experience in learning geometry, but had computer skills. In his research, he investigated Fred through four learning stages, which were: 1. Intuitive learning stage, 2. Analytical learning stage, 3. Inductive learning stage, and 4. Deductive learning stage. During his investigation, he saw that Fred was really enthusiastic doing the given task, and he also found that Fred properly performed the task, and also Fred did the task in a much simpler way than he expected. He also found that the visualization by dynamic computer software helped Fred make some conjectures about relationships between triangles. Even though the background of the participant was different from my participants’ background, the results of his research about using dynamic geometry software shows also that learning through the intervention in which DGS is embedded helps motivate students to learn with more enthusiasm, which could lead students reaching better achievements in their study.

Finally, I want to say that in learning mathematics, motivation is like a spirit of life, which means that learning activities become lively when students have good motivation. Therefore mathematics teachers should be innovative and creative in their teaching method, not only to trigger students’ motivation, but also to maintain students’ motivation.
8. References


9. Bibliography


10. Link references:

http://www.mathopenref.com/angle.html
http://www.geogebra.org/cms/
Appendix A1

Pretest scores

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Appendix A2

The posttest scores

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Appendix B1

The independent-samples t-test of the pretest results

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| Pretest Score    |           |    |       |                |                 |
| Ctrl             | 36        |    | 64.69 | 15.167         | 2.528           |
| Exp              | 36        |    | 67.58 | 18.701         | 3.117           |

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The independent-samples t-test for the posttest results

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<td>3.527</td>
</tr>
<tr>
<td></td>
<td>Exp</td>
<td>35</td>
<td>64.49</td>
<td>21.466</td>
<td>3.628</td>
</tr>
</tbody>
</table>

Independent Samples Test

<table>
<thead>
<tr>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>---</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.413</td>
<td>.522</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-2.965</td>
<td>66.988</td>
</tr>
</tbody>
</table>


Appendix B3

Ancova test of pretest, posttest, and treatment (intervention)

Tests of Between-Subjects Effects

Dependent Variable: postScore

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>10817.473</td>
<td>2</td>
<td>5408.737</td>
<td>15.736</td>
<td>.000</td>
<td>.323</td>
</tr>
<tr>
<td>Intercept</td>
<td>1084.382</td>
<td>1</td>
<td>1084.382</td>
<td>3.155</td>
<td>.080</td>
<td>.046</td>
</tr>
<tr>
<td>PreScore</td>
<td>6936.821</td>
<td>1</td>
<td>6936.821</td>
<td>20.182</td>
<td>.000</td>
<td>.234</td>
</tr>
<tr>
<td>Treatment</td>
<td>3037.530</td>
<td>1</td>
<td>3037.530</td>
<td>8.838</td>
<td>.004</td>
<td>.118</td>
</tr>
<tr>
<td>Error</td>
<td>22684.664</td>
<td>66</td>
<td>343.707</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>258424.750</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>33502.138</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared = .323 (Adjusted R Squared = .302)

Parameter Estimates

Dependent Variable: postScore

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>Std. Error</th>
<th>T</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
</tr>
<tr>
<td>Intercept</td>
<td>23.152</td>
<td>9.720</td>
<td>2.382</td>
<td>.020</td>
<td>3.746</td>
<td>42.558</td>
</tr>
<tr>
<td>PreScore</td>
<td>.605</td>
<td>.135</td>
<td>4.492</td>
<td>.000</td>
<td>.336</td>
<td>.873</td>
</tr>
<tr>
<td>[treatment=exp]</td>
<td>0²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Tests of Between-Subjects Effects

**Dependent Variable: postScore**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>10817.473 a</td>
<td>2</td>
<td>5408.737</td>
<td>15.736</td>
<td>.000</td>
<td>.323</td>
</tr>
<tr>
<td>Intercept</td>
<td>1084.382</td>
<td>1</td>
<td>1084.382</td>
<td>3.155</td>
<td>.080</td>
<td>.046</td>
</tr>
<tr>
<td>PreScore</td>
<td>6936.821</td>
<td>1</td>
<td>6936.821</td>
<td>20.182</td>
<td>.000</td>
<td>.234</td>
</tr>
<tr>
<td>Treatment</td>
<td>3037.530</td>
<td>1</td>
<td>3037.530</td>
<td>8.838</td>
<td>.004</td>
<td>.118</td>
</tr>
<tr>
<td>Error</td>
<td>22684.664</td>
<td>66</td>
<td>343.707</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>258424.750</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. This parameter is set to zero because it is redundant.

### Estimated Marginal Means

**Treatment**

**Estimates**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl</td>
<td>50.339 a</td>
<td>3.185</td>
<td></td>
<td>43.979</td>
<td>56.698</td>
</tr>
<tr>
<td>Exp</td>
<td>63.657 a</td>
<td>3.139</td>
<td></td>
<td>57.389</td>
<td>69.924</td>
</tr>
</tbody>
</table>

a. Covariates appearing in the model are evaluated at the following values:

PreScore = 67.00.
## Pairwise Comparisons

### Dependent Variable: postScore

<table>
<thead>
<tr>
<th>(I) Treatment</th>
<th>(J) Treatment</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval for Difference</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl</td>
<td>Exp</td>
<td>-13.318*</td>
<td>4.480</td>
<td>.004</td>
<td>-22.262 to -4.373</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp</td>
<td>Ctrl</td>
<td>13.318*</td>
<td>4.480</td>
<td>.004</td>
<td>4.373 to 22.262</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on estimated marginal means

* * The mean difference is significant at the .05 level.


## Univariate Tests

### Dependent Variable: postScore

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast</td>
<td>3037.530</td>
<td>1</td>
<td>3037.530</td>
<td>8.838</td>
<td>.004</td>
<td>.118</td>
</tr>
<tr>
<td>Error</td>
<td>22684.664</td>
<td>66</td>
<td>343.707</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The F tests the effect of treatment. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.
Appendix B4

Ancova test of each posttest question

The ancova test for each of the separate questions is shown below, with the required $p$-value = 0.05/15 = 0.0033 to all questions, and with the $p$-value = 0.05/6 = 0.0083 to questions 1, 2, 3, 6a, 6b, and 9, because the researcher expected that the experimental class would do better than the control class does on each question, and the experimental class would be much better than the control class in answering questions 1, 2, 3, 6a, 6b, and 9 (bold). A Bonferroni correction was used to lower the $p$-value criterion appropriately, such that in total the chance of incorrectly finding a significant difference would not rise above 0.05 for each of these two classes of questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Control Class score-mean</th>
<th>Experimental Class score-mean</th>
<th>Sig. value (Treatment)</th>
<th>Sig. value (Pretest)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>5.18</td>
<td>4.09</td>
<td>0.147</td>
<td>0.174</td>
<td>The control class did better than the experimental class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 1.</td>
</tr>
<tr>
<td>2.</td>
<td>2.82</td>
<td>3.06</td>
<td>0.595</td>
<td>0.814</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 2.</td>
</tr>
<tr>
<td>3.</td>
<td>2.50</td>
<td>3.86</td>
<td>0.033</td>
<td>0.37</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 3.</td>
</tr>
<tr>
<td>4a.</td>
<td>3.91</td>
<td>5.14</td>
<td>0.182</td>
<td>0.198</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 4a.</td>
</tr>
<tr>
<td>Question</td>
<td>Control Class score-mean</td>
<td>Experimental Class score-mean</td>
<td>Sig. value (Treatment)</td>
<td>Sig. value (Pretest)</td>
<td>Interpretation</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>------------------------</td>
<td>---------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>4b.</td>
<td>5.88</td>
<td>8.91</td>
<td>0.000</td>
<td>0.928</td>
<td>The experimental class did better than the control class. The treatment is significantly affecting the experimental class, but the pretest does not predict the posttest result for question 4b.</td>
</tr>
<tr>
<td>5a.</td>
<td>5.85</td>
<td>9.46</td>
<td>0.000</td>
<td>0.300</td>
<td>The experimental class did better than the control class. The treatment is significantly affecting the experimental class, but the pretest does not predict the posttest result for question 5a.</td>
</tr>
<tr>
<td>5b.</td>
<td>4.94</td>
<td>6.09</td>
<td>0.240</td>
<td>0.079</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 5b.</td>
</tr>
<tr>
<td>5c.</td>
<td>3.56</td>
<td>4.77</td>
<td>0.245</td>
<td>0.019</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 5c.</td>
</tr>
<tr>
<td>6a.</td>
<td>2.279</td>
<td>2.214</td>
<td>0.694</td>
<td>0.003</td>
<td>The control class did better than the experimental class. The treatment is not significantly affecting the experimental class, but the pretest predicts the posttest result for question 6a.</td>
</tr>
<tr>
<td>6b.</td>
<td>2.279</td>
<td>2.857</td>
<td>0.496</td>
<td>0.000</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, but the pretest predicts the posttest result for question 6c.</td>
</tr>
<tr>
<td>Question</td>
<td>Control Class score-mean</td>
<td>Experimental Class score-mean</td>
<td>Sig. value (Treatment)</td>
<td>Sig. value (Pretest)</td>
<td>Interpretation</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>------------------------</td>
<td>----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>7a</td>
<td>3.456</td>
<td>5.500</td>
<td>0.014</td>
<td>0.000</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, but the pretest predicts the posttest result for question 7a.</td>
</tr>
<tr>
<td>8a</td>
<td>1.18</td>
<td>1.23</td>
<td>0.952</td>
<td>0.270</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 8a.</td>
</tr>
<tr>
<td>8b</td>
<td>1.97</td>
<td>2.74</td>
<td>0.369</td>
<td>0.216</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, and the pretest does not predict the posttest result for question 8b.</td>
</tr>
<tr>
<td>9</td>
<td>2.12</td>
<td>3.00</td>
<td>0.283</td>
<td>0.006</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, but the pretest predicts the posttest result for question 9.</td>
</tr>
<tr>
<td>10</td>
<td>1.56</td>
<td>1.57</td>
<td>0.772</td>
<td>0.000</td>
<td>The experimental class did better than the control class. The treatment is not significantly affecting the experimental class, but the pretest predicts the posttest result for question 10.</td>
</tr>
</tbody>
</table>
Appendix C1

Questionnaire Results

Question 1: What do you think about Geogebra?

<table>
<thead>
<tr>
<th>Student</th>
<th>Students’ Answer (Literal Translation)</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Easy</td>
<td>Help to</td>
<td>Helpful</td>
</tr>
<tr>
<td>1</td>
<td>Interesting and easy to understand because learning through Geogebra very fun and can help to train intuition.</td>
<td>1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>2</td>
<td>Geogebra can help me to learn to understand geometry</td>
<td>0</td>
<td>1 1 1 1</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>3</td>
<td>I could know Geogebra much deeper, learning geometry through Geogebra easy to be processed by my brain or my intuition.</td>
<td>1</td>
<td>1 1 1 1</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>4</td>
<td>By learning through Geogebra I can add my knowledge to learn geometry and Geogebra is very good to understand mathematics.</td>
<td>0</td>
<td>1 1 1 1</td>
<td>0 0 0 0</td>
</tr>
<tr>
<td>5</td>
<td>Geogebra is very fun</td>
<td>0</td>
<td>0 0 0 0</td>
<td>0 1 0 0</td>
</tr>
<tr>
<td>6</td>
<td>My opinion about Geogebra is that Geogebra can be played and help motivating me to learn geometry.</td>
<td>0</td>
<td>0 0 0 0</td>
<td>0 1 1 0</td>
</tr>
</tbody>
</table>

Legend: 1 = answer has this element, 0 = answer does no have this element
<table>
<thead>
<tr>
<th>Question 1: What do you think about Geogebra</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students’ Answer (Literal Translation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>In my opinion learning Geogebra is very fun and can help improving our thinking ability by answering, or asking to friends/teacher, in discussion within group how to understand geometry through Geogebra.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Learning Geogebra is very fun. We are not too much stressed in learning Geogebra, and learning Geogebra very easy to memorize and to understand.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Learning through Geogebra is very fun and we can know exactly about geometry and I am happy because Geogebra can be used for playing and learning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Geogebra is a tool which can help motivating me to learn about geometry by using Geogebra ,very fun and easy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Geogebra can help me to understand about geometry and make me happy and easy to understand geometry.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Geogebra can help me to learn and very easy to learn Geogebra and very fun.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Question 1: What do you think about GeoGebra

<table>
<thead>
<tr>
<th>Student</th>
<th>Students’ Answer (Literal Translation)</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Geogebra can help me to understand geometry. Learning geometry is fun and easy through Geogebra.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Geogebra is very fun and easy, and does not make me stressed. Geogebra can help me to learn to understand geometry.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Learning Geogebra is very fun. Besides learning Geogebra itself, I also can study geometry and can play with Geogebra. Learning through Geogebra I can know parallel lines and ray lines, also can know angles at lines.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Geogebra is very good to learn geometry and learning through Geogebra makes easy to understand and to digest well about geometry.</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>In my opinion learning Geogebra is like learning geometry which makes me easy to understand about geometry.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Geogebra is simple because its windows can be used to draw simple lines. I mean points connecting become a line.</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Student</td>
<td>Students’ Answer (Literal Translation)</td>
<td>Category 1</td>
<td>Category 2</td>
<td>Category 3</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>19</td>
<td>Geogebra can help me to understand geometry and make easy to understand in learning about geometry, very fun, easy to understand.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>Geogebra makes me know everything.</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>Geogebra makes us really easy to learn geometry through Geogebra, besides easy we also can quickly understand about Geogebra.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>Geogebra helps me to understand about geometry.</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>Geogebra helps motivating me to learn geometry and to know it. Learning geometry through Geogebra is very good.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>Geogebra is a fun subject. Geogebra also can help motivating me to learn geometry.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Student</td>
<td>Students’ Answer (Literal Translation)</td>
<td>Category 1</td>
<td>Category 2</td>
<td>Category 3</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>25</td>
<td>Geogebra is very helpful in learning and making us enjoy learning geometry.</td>
<td>0 1 1 1</td>
<td>1 0 0 0</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>Geogebra is a fun subject which means we can play, while learning. In my opinion learning through Geogebra is not stressed, so we can engage in learning without stressed feeling.</td>
<td>0 0 0 0</td>
<td>1 1 0 0</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>Geogebra is very fun and easy to use and also can help me learning geometry. Playing Geogebra can also help knowing parallel lines and ray lines and also knowing angel between lines.</td>
<td>1 1 1 1</td>
<td>0 1 0 0</td>
<td>1</td>
</tr>
<tr>
<td>28</td>
<td>I am happy be able to learn Geogebra because I can know geometry through Geogebra and I like it so much.</td>
<td>0 1 0 1</td>
<td>1 0 0 0</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>In my opinion Geogebra is a kind of subject which is very fun and easy to understand geometry.</td>
<td>1 1 0 1</td>
<td>0 1 0 0</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>Happy be able to learn Geogebra because geogebra makes me easy to learn geometry.</td>
<td>1 1 0 1</td>
<td>0 0 0 0</td>
<td>0</td>
</tr>
<tr>
<td>Student</td>
<td>Students’ Answer (Literal Translation)</td>
<td>Easy</td>
<td>Help to understand</td>
<td>Helpful</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------</td>
<td>-------------------</td>
<td>---------</td>
</tr>
<tr>
<td>31</td>
<td>Geogebra is really fun, I can learn while playing and I also can know any shape of angle during learning and trying out Geogebra. Geogebra helps me to understand about geometry much better. Learning Geogebra while doing questions is very fun and enjoyable and at the same time I get some knowledge much deeper.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>Geogebra is very good because through Geogebra we can learn geometry easily, quickly, and accurately to understand.</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>Geogebra helps me to understand geometry. Learning through Geogebra is very fun and easy. By availability of Geogebra I can try it at home and learn it. Geogebra motivates me to learn geometry.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>34</td>
<td>Geogebra helps me in learning geometry. By Geogebra I can understand geometry much better. Geogebra is very fun and easy.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>Geogebra is a way to learn mathematics using computers, and my opinion learning Geogebra is very fun and makes easy to learn and to understand geometry. Learning Geogebra in my opinion can help motivating every student to learn geometry easily and fun.</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

| Total   | 20   | 28   | 14   | 30   | 8    | 21  | 6    | 2    | 25  |
### Questionnaire 2-11 Results

<table>
<thead>
<tr>
<th>No.</th>
<th>Questionnaire</th>
<th>Totally agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Totally disagree</th>
<th>Researcher’s interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Geogebra can help motivating me to learn geometry.</td>
<td>14</td>
<td>19</td>
<td>2</td>
<td>0</td>
<td></td>
<td>94.3% students stated that Geogebra had motivated them in learning geometry. 5.7% students were neutral.</td>
</tr>
<tr>
<td>3.</td>
<td>Geogebra helps me to understand about geometry much better.</td>
<td>20</td>
<td>14</td>
<td>1</td>
<td>0</td>
<td></td>
<td>97.1% students stated Geogebra helps them to understand Geogebra much better. 2.9% students were neutral.</td>
</tr>
<tr>
<td>4.</td>
<td>Learning geometry through Geogebra is fun and easy.</td>
<td>17</td>
<td>11</td>
<td>7</td>
<td>0</td>
<td></td>
<td>80% students stated Geogebra makes learning geometry easy and fun. 20% students were neutral.</td>
</tr>
<tr>
<td>5.</td>
<td>Geogebra makes me confused to understand geometry.</td>
<td>1</td>
<td>6</td>
<td>21</td>
<td>7</td>
<td></td>
<td>80% students stated Geogebra does not make them confused to understand geometry. 17% students were neutral. 3% students stated Geogebra makes them confused to understand geometry.</td>
</tr>
<tr>
<td>6.</td>
<td>Geogebra is difficult to use to learn geometry.</td>
<td>1</td>
<td>5</td>
<td>15</td>
<td>14</td>
<td></td>
<td>83% students stated Geogebra is not difficult to use to learn geometry. 14% students were neutral. 3% students stated Geogebra is difficult to use to learn geometry.</td>
</tr>
<tr>
<td>7.</td>
<td>Geogebra takes a lot of my time to be understood to learn geometry.</td>
<td>5</td>
<td>7</td>
<td>13</td>
<td>10</td>
<td></td>
<td>66% students stated Geogebra does not take</td>
</tr>
<tr>
<td>No.</td>
<td>Questionnaire</td>
<td>Totally agree</td>
<td>Agree</td>
<td>Neutral</td>
<td>Totally disagree</td>
<td>Researcher's interpretation</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------</td>
<td>----------------</td>
<td>-------</td>
<td>---------</td>
<td>------------------</td>
<td>----------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a lot of time to be understood to learn geometry. 20% students were neutral. 14% students stated Geogebra takes a lot of time to be understood to learn geometry.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Learning geometry through Geogebra is useless.</td>
<td>1</td>
<td>9</td>
<td>25</td>
<td></td>
<td>97.1% students stated learning geometry through Geogebra is not useless. 2.9% students stated learning geometry through Geogebra is useless.</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>I will always use Geogebra to learn geometry furthermore in the future.</td>
<td>7</td>
<td>17</td>
<td>10</td>
<td>1</td>
<td>68.6% students stated they will use Geogebra to learn geometry furthermore in the future. 28.6% students were neutral. 2.8% students stated they will not use Geogebra in the future to learn geometry.</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Learning geometry through Geogebra is very exciting.</td>
<td>9</td>
<td>20</td>
<td>6</td>
<td></td>
<td>82.9% students stated learning geometry through Geogebra is very exciting. 17.1% students were neutral.</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>I prefer learning geometry without Geogebra to learning through Geogebra.</td>
<td>1</td>
<td>19</td>
<td>14</td>
<td>1</td>
<td>42.9% students stated they prefer learning geometry through Geogebra. 54.2% students were neutral. 2.9% students stated they prefer learning geometry without Geogebra.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D1

Teacher Interview

After two months of the intervention done, the researcher interviewed to the collaborative teacher, asking her some questions about her students and her class.

<table>
<thead>
<tr>
<th>No.</th>
<th>The researcher</th>
<th>The collaborative teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hi, how are you?</td>
<td>I’m fine thank you. How about you?</td>
</tr>
<tr>
<td>2.</td>
<td>I’m good. Thank you. ...</td>
<td>Sorry, I need your help to answer some questions. Can you help me?</td>
</tr>
<tr>
<td></td>
<td>Yes, sure. What’s the question?</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>First of all, I want to know how students of the experimental class are?</td>
<td>Oh, they are fine. Actually they missed you after your intervention’s done.</td>
</tr>
<tr>
<td>4.</td>
<td>Oh, nice to hear that. But, can you tell me more about them? I mean how their behavior toward learning mathematics in your class is?</td>
<td>Hmmmm... I think they showed some positive behavior in my class. They became more confident, more critical, and more enthusiastic learning mathematics in my class.</td>
</tr>
<tr>
<td>5.</td>
<td>Woow... That’s wonderful. Anyway, do you think that it happened because of my intervention?</td>
<td>I think so... Because before your intervention, they didn’t show the behavior like that. I think they’ve been motivated by your intervention.</td>
</tr>
<tr>
<td>6.</td>
<td>Hmmmm... I’m glad to hear that my intervention gave positive contributions to students in learning mathematics.</td>
<td>Yes, I’m happy as well. Because now I a bit know that my students actually have interests in learning mathematics. I also saw a special case about my student, Sindi.</td>
</tr>
<tr>
<td>7.</td>
<td>What’s that?</td>
<td>Before your intervention, Sindi was not seen as a student with a good talent in mathematics. She just was like common student who did not feel enthusiastic during mathematics class. But after the intervention, I can see that she is really significantly different now.</td>
</tr>
<tr>
<td>8.</td>
<td>(Just listening)</td>
<td>Now she looks smart, and she also got score in</td>
</tr>
<tr>
<td>No.</td>
<td>The researcher</td>
<td>The collaborative teacher</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>9.</td>
<td>The researcher</td>
<td>the final test in mathematics higher than Budiono got. Actually, Budiono is the smart student and is the class star.</td>
</tr>
<tr>
<td>9.</td>
<td>Hmmm... interesting.</td>
<td>One more thing that made me happy is that Sindi’s sister, Sinta shown the same phenomena as Sindi did, even though Santi was not a student in the experimental class. I think they always discussed and studied mathematics together at their home.</td>
</tr>
<tr>
<td>10.</td>
<td>Okay, that’s really nice story after my intervention. Thank you so much you told me about that. I want to ask you other questions. What do you think about the intervention I have done?</td>
<td>I think your intervention was running well. I can say like that because I was in your class during the intervention, and I saw the students really engaged and enjoy your teaching. Because before your intervention, they didn’t get any kind of teaching mathematics through computers yet, especially through Geogebra.</td>
</tr>
<tr>
<td>11.</td>
<td>Did you continue using Geogebra after my intervention?</td>
<td>No, I didn’t. Actually, I wanted to continue teaching geometry through Geogebra, but I had problems with some technical issues.</td>
</tr>
<tr>
<td>12.</td>
<td>What kinds of technical issues did you face?</td>
<td>As you knew that computers in our lab were not enough to at least three students at one computer. Another problem was that I couldn’t teach using Geogebra to all 4 classes, because some of my classes have the same time with other teachers’ classes in using computer lab.</td>
</tr>
<tr>
<td>13.</td>
<td>Hmmm... I could understand about that. But, what do you think about Geogebra itself?</td>
<td>I think Geogebra is nice software to use to teach geometry. It’s really helpful and easy to understand geometry, that’s why students really love Geogebra. Honestly, I’m a bit confused how</td>
</tr>
<tr>
<td>No.</td>
<td>The researcher</td>
<td>The collaborative teacher</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to maintain the students’ motivation in learning mathematics without using computers in my teaching.</td>
</tr>
<tr>
<td>14.</td>
<td>Will you use Geogebra to teach geometry in the future, if the problems you face right now are solved?</td>
<td>Yes, I think I will do it.</td>
</tr>
<tr>
<td>15.</td>
<td>Thank you so much for the conversation. And I want to thanks also to all your help in my research.</td>
<td>You’re welcome. I’m glad, I could help you.</td>
</tr>
</tbody>
</table>
Appendix D2

Student Interview Results

The researcher interviewed three students, Fitri, Lisa, and Ozy, where they were asked some questions.

Fitri Interview

<table>
<thead>
<tr>
<th>No.</th>
<th>The Researcher</th>
<th>Fitri</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hello Fitri.</td>
<td>I’m well sir. Thank you.</td>
</tr>
<tr>
<td></td>
<td>How are you today?</td>
<td>How about you sir?</td>
</tr>
<tr>
<td>2.</td>
<td>I’m okay, thank you.</td>
<td>What can I do for you sir?</td>
</tr>
<tr>
<td></td>
<td>By the way, I need your help Fitri.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>I just want to ask you some questions about my intervention.</td>
<td>Oo.. that’s okay sir. I hope I can answer your questions sir.</td>
</tr>
<tr>
<td>4.</td>
<td>Firstly, I want to know your opinion. What do you think about Geogebra?</td>
<td>In my opinion, Geogebra is fun, because I could play with Geogebra while learning geometry, sir.</td>
</tr>
<tr>
<td>5.</td>
<td>Did Geogebra help you to understand geometry?</td>
<td>Yes, it did helped me much to understand geometry sir. Because it made me understand something that I didn’t understand yet.</td>
</tr>
<tr>
<td>6.</td>
<td>Okay. That’s good for you. Did you have any problem in learning geometry through Geogebra?</td>
<td>No, I didn’t any have problem sir, except the computer sometimes didn’t work well, sir. I think Geogebra is easy to use sir.</td>
</tr>
<tr>
<td>7.</td>
<td>Yes, I knew about the computer. Did Miss Ari teach geometry through Geogebra as well after my intervention?</td>
<td>No, she didn’t sir.</td>
</tr>
<tr>
<td>8.</td>
<td>Anyway, which one do you prefer, Fitri? Learning geometry through Geogebra or learning geometry without through Geogebra?</td>
<td>I prefer learning geometry through Geogebra sir. Because it helped me much to understand geometry.</td>
</tr>
<tr>
<td>9.</td>
<td>Okay... This is the last question, Fitri. Do you think Geogebra helped you in improving your skills in reasoning, intuition, and measuring?</td>
<td>Yes, it helped me to improve all those skills, sir.</td>
</tr>
<tr>
<td>11.</td>
<td>I hope you succeed in your study.</td>
<td>Thank you sir.</td>
</tr>
</tbody>
</table>
## Lisa Interview

<table>
<thead>
<tr>
<th>No.</th>
<th>The Researcher</th>
<th>Lisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hi Lisa. How are you doing?</td>
<td>I’m fine sir. Thank you. How about you sir?</td>
</tr>
<tr>
<td>2.</td>
<td>I’m good, thank you. How’s your study?</td>
<td>It’s running well sir. Actually, I missed you to teach us again sir.</td>
</tr>
<tr>
<td>4.</td>
<td>Okay, thank you Lisa. Lisa, what do you think about Geogebra?</td>
<td>In my opinion, Geogebra is fun… easy to use… and gave me some new knowledge. For sure… Geogebra is fun for me, sir.</td>
</tr>
<tr>
<td>5.</td>
<td>Did Geogebra help you to understand geometry?</td>
<td>Yes, it did sir, indeed.</td>
</tr>
<tr>
<td>6.</td>
<td>Did you have problem in learning geometry through Geogebra?</td>
<td>Hmmm… I think I didn’t really have any problem in using Geogebra and learning geometry through it. I think the problem was only the total of computers was not enough to give each student opportunity to experience with Geogebra a lot.</td>
</tr>
<tr>
<td>7.</td>
<td>Yes, I agree that the total of computers we had was not sufficient enough. And I’m sorry about that. Anyway, which one do you prefer Lisa? Learning geometry through Geogebra or learning geometry without through Geogebra?</td>
<td>I prefer learning geometry through Geogebra sir. Because it helped me much to understand geometry.</td>
</tr>
<tr>
<td>8.</td>
<td>Okay… Do you think Geogebra helped you in improving your skills in reasoning, intuition, and measuring?</td>
<td>Yes, I think it helped me enough to drill all those skills, sir.</td>
</tr>
<tr>
<td>9.</td>
<td>Okay Lisa. Thank you so much for your help.</td>
<td>You’re welcome sir. I’m pleased be able to help you.</td>
</tr>
<tr>
<td>10.</td>
<td>I hope you succeed in your study.</td>
<td>Thank you sir.</td>
</tr>
</tbody>
</table>
## Ozy Interview

<table>
<thead>
<tr>
<th>No.</th>
<th>The Researcher</th>
<th>Lisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hello Ozy. How are you today?</td>
<td>I’m okay sir. Thank you. How about you sir?</td>
</tr>
<tr>
<td>2.</td>
<td>I’m okay too, thank you. How’s your study?</td>
<td>It’s fine sir. Everything is running well.</td>
</tr>
<tr>
<td>3.</td>
<td>Nice to hear that. Anyway, I need your time to answer some questions about my intervention. Could you help me?</td>
<td>No problem sir. What’s the question sir?</td>
</tr>
<tr>
<td>4.</td>
<td>First of all, I want ask you...what do you think about Geogebra?</td>
<td>Geogebra is good to learn... easy to use... and of course it’s fun for me, sir. I’ve installed it in my own computer as well sir, after you gave me the copy of Geogebra software.</td>
</tr>
<tr>
<td>5.</td>
<td>Oh, it’s nice you have it on your own computer, so you can use it whenever you need.</td>
<td>Yes, it is sir.</td>
</tr>
<tr>
<td>6.</td>
<td>Did Geogebra help you to understand geometry?</td>
<td>Yes, Geogebra helped me much to understand geometry sir, because it gave me a lot opportunity to explore and to understand many kinds of geometrical shapes.</td>
</tr>
<tr>
<td>7.</td>
<td>Okay, that’s good for you. But, did you have problem in learning geometry through Geogebra in my intervention?</td>
<td>Hmmm... I didn’t have any problem in using Geogebra and learning geometry through it. Because even though we didn’t have many computers in our lab, I had already learned it in my own computer sir.</td>
</tr>
<tr>
<td>8.</td>
<td>I’m glad that you have a good motivation to learn Geogebra at home. Anyway, which one do you prefer Ozy? Learning geometry through Geogebra or learning geometry without through Geogebra?</td>
<td>Actually, I like both sir. But, of course, I prefer more learning geometry through Geogebra sir. Because it helped me to understand that I didn’t understand when learning geometry without Geogebra.</td>
</tr>
<tr>
<td>9.</td>
<td>Okay... So you had a lot positive effect of Geogebra. The last question for you Ozy. Do you think Geogebra helped you in improving your skills in reasoning, intuition, and measuring?</td>
<td>Yes, indeed sir. Geogebra helped me enough to drill and to improve all those skills, sir.</td>
</tr>
<tr>
<td>10.</td>
<td>Okay Ozy. Thank you so much for your time.</td>
<td>You’re welcome sir. I’m pleased be able to talk to you</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
| 11. | Me too Ozy.  
     | I hope you succeed in your study. | Thank you sir. |
| 12. | See later Ozy | See later sir. |
Appendix E1

Teacher’s Manual 1

The first activity for the first meeting

The general aim:

“Students will be able to recognize relationship between two or more lines.”

The research aim:

“Students will be able to use their intuition and reasoning skills in this activity”

In this activity the teacher will show a real transparent block to students to identify the relationships between sides or edges of the block. After that the teacher show the picture of the block by using projector slides and also distributes the picture on the paper work to students. In this activity students are asked to answer all below questions just by seeing and reasoning. During the class activities the teacher should also helps students whom face problems to answer the questions in this activity.

Location of time: 40 minutes (reading, answering, and discussion time)

1. Please look at the picture below:
a. How many corner points of meeting points of edges of the block above?
(The aim: students will be able to identify the corner points of the block)

Expected answer: There are 8 corner points.

Approximated time to read and to answer: 1 minute.

In this question students will be asked to use their intuition skill.

b. How many edges are there meeting at every one corner point?
(The aim: students will able to understand that the corner point is the meeting point of some edges of the block)

Expected answer: There are 3 edges that meet at every one corner point.

Approximated time to read and answer: 1 minute.

In this question students will be asked to use their intuition skill.

c. Write down a group of edges that meet each other at a corner point.
(The aim: students can identify the name of every edge that meets at one common corner point)

Expected answer: some possible answers, the first group is AB, AD, and AE; the second group is BA, BC, and BF.

Approximated time to read and to answer: 1.5 minute.

In this question students will be asked to use their intuition skill.
d. Write down three edges that do not meet each other.

(The aim: students will be able to investigate the edges that are not meeting at one common corner point)

Expected answer: 1st pair is AB and CD, 2nd pair is BC and EH, and 3rd pair is AB and EH.

Approximated time to read and to answer: 1.5 minutes.

In this question students will be asked to use their intuition skill.

e. Please give a reason why some edges can meet at a common corner point.

(The aim: students will be able to give their own reasons on their answers and understanding about the relationships of edges that meets at one common corner point)

Expected answer: there some edges meeting at corner points because they are not parallel each other and must be on the same plane.

Approximated time to read and to answer: 2 minutes.

In this question students will be asked to use their reasoning skill.

f. Look carefully at edges that do not meet at corner points. For example, the relationship between AB and EF, and also between AE and CD. What is your conclusion on the relationship of those example pairs of edges?

(The aim: students will be able to make their own words to describe the other relationships between edges that do not meet at one common corner point)

Expected answer: AB and EF are parallel and they do not meet at any point at all. AE and CD are not parallel, they are not at the same face, and they do not meet.
at any point as well. The conclusion is that two edges will not meet each other not only one possible reason which is that they are parallel, but also there is another possible reason, which is that they are not parallel and not at the same face as well. The edges are like AE and CD called crossing-lines or crossing-edges.

Approximated time: 5 minutes.

In this question students will be asked to use their intuition skill and reasoning skills.

g. How many possibilities of relationship between two edges of the block are there? (The aim: students will be able to know all the possibilities of relationships between edges of the block)

Expected answer: there are 3 possibilities of the relationship between 2 edges of the block, which are 1st parallel edges, 2nd un-parallel edges, and 3rd crossing-edges.

Approximated time to read and to answer: 2 minutes.

In this question students will be asked to use their intuition skill.

h. Write down your conclusion of your observation at the picture above, when do two edges meet at one point, and when do two edges not meet at one point? (The aim: students will able to make their final conclusion on what they have just learned during class activities)

Expected answer: two edges will meet at one common point if they are not parallel and they are on the same face. Two edges will not meet at one common point if they are parallel, or they are not parallel but not on the same face.
Approximated time to read and to answer: 3 minutes.

In this question students will be asked to use their reasoning skill.
Appendix E2

Activity 1 with GeoGebra for the first meeting

1. Draw a pair of parallel lines.
   ✓ Use the tool “Line through two points” to draw a line.
   ✓ Use the tool “Parallel lines” to draw a parallel line to the first one.

2. Draw a pair of perpendicular lines
   ✓ Use the tool “Line through two points” to draw a line.
   ✓ Use the tool “Perpendicular line” to draw a perpendicular line to the first one.
3. Please draw a picture like below

4. Please draw a picture like below
5. Please draw a picture like below

6. Please draw a picture like below
7. Please draw a picture like below

![Diagram](image1)

8. From the last picture you drawn, please make it like below

![Diagram](image2)

9. What is the picture that you have drawn?
Appendix E3

Teacher’s Manual 2

The second activity for the second meeting

The general aim: students will be able to recognize how an angle can be form and also to know what the important elements of an angle to have.

The research aim:

“Students will be able to use their intuition and reasoning skills in this activity”

In this activity the teacher asks students to take two small sticks, and then asks them to join the end of each stick so that forms an angle shape. After that the teacher asks students to make their own words about what the important elements of an angle. The teacher also asks students to distinguish between a small angle and a big angle.

Location of time: 40 minutes (reading, answering, and discussion time)

1. Take two small and short sticks, then join their end point and also give a name to every end of the sticks by A, B, and C like picture below:
a. What are the points A, B, and C for in the picture above?

(The aim: students will be able to understand that an angle formed by two lines)

*Expected answer: to name sticks as segment line AB and segment line AC.*

*Approximated time to read and to answer: 1 minute.*

*In this question the students are asked to use their intuition skill.*

b. How do you call the figure formed by both sticks above?

(The aim: students will be able to recognize an angle shape)

*Expected answer: an angle BAC or an angle CAB or just an angle.*

*Approximated time to read and to answer: 1 minute.*

*In this question students are asked to use their intuition skill.*

c. If every stick represents a segment line that related to the picture, then what is the reason those segments can form an angle?

(The aim: students will be able to understand that an angle can be formed by two different lines that are not parallel)

*Expected answer: because those lines are not parallel each other.*

*Approximated time to read and to answer: 1 minute.*

*In this question students are asked to use their reasoning skill.*
d. What are the important elements of an angle?

(The aim: students will be able to understand and to know that the important elements of an angle are a corner point, and two legs of the angle, and also the name of the angle itself that are depending on the name of the end point of every line that forms the angle)

Expected answer: the important elements of an angle are (1) the corner point which is the intersecting point of two lines, (2) the legs of an angle which is the lines that are intersecting each other, (3) the name of every end point of an angle.

Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their reasoning skill.

2. Look at the picture below:

![Diagram of intersecting lines with points A, B, C, E, and D]

a. How many angles are there that you can identify from the picture above?

(The aim: students will be able to recognize many angles that are put at one common corner point)

Expected answer: there are 3 angles, 4 angles, or 6 angles in that picture.
Approximated time to read and answer: 2 minutes.

In this question students are asked to use their intuition skill.

b. Can you recognize which one of angles that is the biggest one? Please give your reason.
(The aim: students will be able to recognize an angle with big size)

Expected answer: the biggest angle is angle EAD or angle DAE because angle EAD is composed by other angles.

Approximated time to read and answer: 2 minutes.

In this question students are asked to use their intuition and reasoning skills.

3. Look at the picture below:

![Image of a traditional house](http://jepretanku.files.wordpress.com/2008/03/rumah-aceh-traditional-house1.jpg)

Source: [http://jepretanku.files.wordpress.com/2008/03/rumah-aceh-traditional-house1.jpg](http://jepretanku.files.wordpress.com/2008/03/rumah-aceh-traditional-house1.jpg)

a. Which parts of the house are forming angles? Please give your reason.
(The aim: students will be able to recognize every shape in their real life that forms an angle shape)

Expected answer: one possible answer is that the roof of the house because both sides of the roof are not parallel and meeting at one corner point.

Approximated time to read and to answer: 1 minute.

In this question students are asked to use their intuition and reasoning skills.

b. Which parts of the house are not forming angles? Please give your reason.

(The aim: students will be able to recognize every shape in their real life that does not form an angle shape)

Expected answer: one possible answer is that the pillars of the house because both every pillar of the house are parallel and not meeting at one corner point.

Approximated time to read and to answer: 1 minute.

In this question students are asked to use their intuition and reasoning skills.
Appendix E4

Activity 2 with GeoGebra for the second meeting

1. Draw picture like below

2. Construct the angle between those two segment lines above.

3. How many possibilities of angle picture can you construct between them?

4. Do they have the same size?

5. Draw pictures like below

6. How many angles for each picture above are there?

7. Can you see a pattern of those numbers of angles?
8. Can you guess how many angles if there are 5 segment lines meeting at one common point?
Appendix E5

Teacher’s Manual 3 for the 3\textsuperscript{th} meeting

The third activity

The general aim:

“Students will be able to recognize any size of angles.”

The research aim:

“Students will be able to use their intuition and reasoning skills in this activity”

In this activity the teacher will give some tasks about how to guess and recognize any size of some angles. The teacher gives some clues and assists to students when students find difficult to answer the questions in the tasks. Students are asked to answer all the questions with their intuition skill and to use their reasoning skill.

\textbf{Location of time}: 40 minutes (reading, answering, and discussion time)

1. Draw a circle with a certain diameter that appropriate to your paper like picture below:

![Circle Diagram]

a. Do you remember how much degrees of one full rotation of a circle?
(The aim: students will be able to remember the degrees of one full rotation of a circle)

Expected answer: $360^\circ$

Approximated time to read and answer: 1 minute.

In this question students are asked to use their intuition skill.

b. Please give your reason why AOB can be regarded as an angle.

(The aim: students will be able to recognize a straight angle)

Expected answer: AOB is an angle, which is a straight angle. It considered as an angle because it has two legs of an angle (AO and OB) and one central corner point (O).

Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their intuition and reasoning skills.

c. How big is the size of angle AOB? Do you need a tool for measuring the angle AOB? Or can you simply use your intuition to get the degree of the angle?

(The aim: The aim of this question is: students will be able to know the size of a half of a circle)

Expected answer: No, I don’t need a tool to measure the angle AOB, because I can simply use my intuition by dividing one full rotation by 2, so the angle AOB is $180^\circ$.

Approximated time to read and to answer: 2 minutes.
In this question students are asked to use their intuition and reasoning skills, however, in other possibility to use their measuring skill.

d. Can the angle AOB be representing as a straight angle? Give your reason.
(The aim: students will be able to understand that a straight angle can be represented by any straight line)

Expected answer: Yes, it can be, because the angle AOB is lying on the diameter AB where diameter AB is a straight line.

Approximated time to read and to answer: 1 minute.

In this question students are asked to use their intuition and reasoning skills.

2. Look at the picture below:

![Diagram](image)

a. Write down three angles that can be formed by those points on the lines that you can define.
(The aim: students will be able to recognize angles that formed by any point lying on a straight line)

Expected answer: some possibilities are angle ABC, angle BCD, and angle CED.
Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their intuition skill.

b. Please without using a protractor, write down the size of each angle you mentioned in the previous question.
(The aim: students will be able to compare between zero angle and 180° angle)

Expected answer: angle ABC = 180°, angle BCD = 180°, and angle CED = 0°.

Approximated time to read and to answer: 1 minute.

In this question students are asked to use their intuition and reasoning skills.

c. Is angle ABC bigger than angle BCD? Give your reason.
(The aim: students will be able to understand that an angle is not depending on the size of their legs)

Expected answer: angle ABC is the same as angle BCD, because both of them are equal to 180°.

Approximated time to read to answer: 1 minute.

In this question students are asked to use their intuition and reasoning skills.
3. Look at the pictures below:

![Diagram with points A, C, D, E, M, L, D, P]

a. Without using a protractor, please, try to answer the question whether angle EDF bigger than angle MKL? Give your reason.

*(The aim: students will be able to recognize a small difference degree between two angles)*

*Expected answer: angle EDF is smaller than angle LKM, because angle EDF looks much sharper than angle LKM.*

*Approximated time to read and to answer: 1 minute.*

*In this question students are asked to use their intuition and reasoning skills.*

b. With your intuition, please try to guess the degree of each angle of the picture above? Please give your reason.

*(The aim: students will be able to guess degrees of some angles)*

*Expected answer:*

angle BAC = $90^\circ$ *(because angle BAC looks a half of straight angle)*, angle EDF = $45^\circ$ *(because angle EDF looks a half of angle BAC)*,

angle LKM = $60^\circ$ *(because angle LKM is a bit bigger than angle EDF)*,

and angle POQ = $30^\circ$ *(because angle POQ looks a half of angle LKM).*
Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their intuition and reasoning skills.
Appendix E6

Activity 3 with GeoGebra for the 3\textsuperscript{th} meeting

1. Draw picture like below

![GeoGebra screenshot]

2. Measure the small angle AOB and the big angle AOB. Calculate the sum of them.

3. Drag point B around the circle. Investigate the changes of those angles whether they have the same sum with the sum of the previous one.

4. When does the condition happen, where the small angle AOB and the big angle AOB having the same size?

5. When does the small angle AOB reach the smallest size?
6. Draw picture like below

7. Measure angle ABC, angle ABD, and angle BCD. Are they the same in size? Why?
8. Measure angle ACB, angle BCA, and angle DBC. Are they the same in size? Why?
Appendix E7

Teacher’s Manual 4 for the 4th meeting

The forth activity:

The general aim:

“Students will be able to measure any size of angles.”

The research aim:

“Students will be able to use their intuition, measuring, and reasoning skills in this activity”

In this activity the teacher will give some tasks about determining any size of some angles. Students are asked to use their intuition, measuring, and reasoning skills to answer all the questions. During the class activities the teacher also helps students whom face problems to answer the questions in this activity.

Location of time: 40 minutes (reading, answering, and discussion time)

1. Look at the picture below:

Is angle BAC bigger than angle DAE? Please give your reason.
(The aim: students will be able to understand that every angle that their each leg is lying on the same lines then they are the same angle)

Expected answer: angle BAC is neither bigger nor smaller than angle DAE, because their legs are lying on the same lines.

Approximated time to read and to answer: 1 minute.

In this question students are asked to use their intuition and reason skills.

2. Look at the pictures below:

a. Before using protractor, please give your estimation by using your intuition to every angle.
(The aim: students will be able to estimate size of angles by their intuition only)

Expected answer: angle BAC = 120\(^0\), angle HGJ = 270\(^0\), angle DFE = 280\(^0\), and angle KLM = 225\(^0\).

Approximated time to read and to answer: 3 minutes.

In this question students are asked their intuition skill.
b. By using protractor, find out all the degrees of the angles.

(The aim: students will be able to measure angles by using protractor)

Expected answer: angle $BAC = 120^0$, angle $HGI = 270^0$, angle $DFE = 280^0$, and angle $KLM = 225^0$.

Approximated time to read and to answer: 4 minutes.

In this question students are asked to use their measuring skill.

c. Did you find difficult in finding out all those angles by using protractor? How did you do to overcome the difficulty? Please give your explanation.

(The aim: students will be able to evaluate the problems they face using protractor)

Expected answer: the problem is when measuring angles that are more than $180^0$. To overcome the problem first of all, measuring the small one then after that subtracting it by $360^0$, because the sum of big one and small one angles is $360^0$.

In this question students are asked to use their reasoning skill.

3. Angle between $0^0$ and $90^0$ called acute angle, angle between $90^0$ and $180^0$ called obtuse angle, angle with degree $90^0$ called right angle, and angle with degree $180^0$ called straight angle.

Look at the pictures below:
d. Use your intuition to classify all angles above in their category.

(The aim: students will be able to classify angles into their groups using intuition)

Expected answer: the group of acute angles: angle BAC, and angle NMO. The group of obtuse angles: angle EDF, and angle HGI. The group of right angle: only angle QPR. The group of straight angle: only angle KJL.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their intuition skill.

e. Use protractor to classify all angles above in their category.

(The aim: students will be able to classify angles into their angles using protractor)

Expected answer: the group of acute angles: angle BAC, and angle NMO. The group of obtuse angles: angle EDF, and angle HGI. The group of right angle: only angle QPR. The group of straight angle: only angle KJL.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their measuring skill.
f. Is there any different result between those two ways? Give your explanation.

(The aim: students will be able to compare their result between using intuition and using protractor)

Expected answer: there is different result between those two ways of finding the size of angles, because sometimes intuition leads mistakes and measuring sometimes gives some error calculation.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their reasoning skill.
Appendix E8

Activity 4 with GeoGebra for the 4th meeting

1. Draw picture like below

![GeoGebra Diagram](image1)

2. Measure angle BAC.

3. Extend segment line AB, and AC like picture below

![GeoGebra Diagram](image2)

4. Measure angle DAE. Compare with angle BAC. Do they have different size? Why?
5. Draw picture like below

![Diagram](image)

6. Measure angle GHI, angle GIH, and angle HGI.

7. Drag any point excluded point G, H, and I. See what happen with the sum of angles GHI, GIH, and HGI.

8. What is your conclusion on what you have done?
9. Draw pictures like below

10. Triangle ABC above is called an obtuse triangle. Do you know why the reason is?
11. Please draw a right triangle, and an acute triangle.
The fifth activity:

The general aim:

“Students will be able to understand and recognize relationship between angles.”

The research aim:

“Students will be able to use their intuition and reasoning skills in this activity”

In this activity the teacher will give some tasks about recognizing relationships between angles. Students are asked to use their intuition, and reasoning skills. During the class activities the teacher also helps students whom face problems to answer the questions in this activity.

Location of time: 40 minutes (reading, answering, and discussion time)

1. Look at the pictures below:
a. Without using a protractor, can you calculate angle DAB if angle CAD, angle CAB are known? If so, how would you do it?

(The aim: students will be able to understand that angle DAB can be calculated by subtracting angle CAD to angle CAB)

Expected answer: yes, angle DAB can be calculated, because angle BAE is a part of angle BAD and angle EAD is also a part of angle BAD, so by subtracting angle EAD to angle BAD will lead to get angle BAE.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their intuition and reasoning skills.

b. Without using a protractor, can you calculate angle GFE if angle GFH and angle HFE are known? If yes, how would you do it?

(The aim: students will be able to understand that angle GFE can be calculated by adding angle GFH and angle HFE)

Expected answer: yes, angle GFE can be calculated, because angle GFE is shaped by angle GFH and angle HFE, so by adding angle GFH and angle HFE will lead to get angle GFE.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their intuition and reasoning skills.

c. Please use a protractor to measure all the degrees of angles above, and compare the result to your previous answers of the question a, and b. Is there any difference between the results of the two ways? Why?

(The aim: students will be able to compare their intuition skill and measuring skill)
Expected answer: The first one is subtraction of angles, meanwhile the second one is the addition of angles.

Approximated time to read and to answer: 3 minutes.

In this question students are asked to use their measuring and reasoning skills.

Note:

- Two angles that have the sum of them equal to $90^0$ are called complementary angles of each other.
- Two angles that have the sum of them equal to $180^0$ are called supplementary angles of each other.
2. Look at the picture below:

![Diagram of intersecting lines AB and CD at point E]

a. AB and CD are the segment lines intersecting at point E. Please write down angles that are supplementary angles each other.

(The aim: students will be able to recognize supplementary angles from intersecting two angles)

Expected answer: angle AEC together with angle CEB, angle CEB together with angle BED, angle BED together with angle DEA, and also angle DEA together with angle AEC.

Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their intuition skill.

b. Based on your intuition, are there any angle having the same degree? Give your argumentation.

(The aim: students will be able to recognize angles that have the same size from the intersection of two lines)
Expected answer: Yes there are some angles have the same degree, angle AEC must be the same as angle BED, because angle AEC + angle CEB = 180°, meanwhile angle CEB + angle BED = 180° as well.

Another the same angles are angle CEB and angle DEA, because angle CEB + angle BED = 180°, and angle BED + angle DEA = 180° as well.

Approximated answer to read and to answer: 4 minutes.

In this question students are asked to use their intuition and reasoning skills.

3. Look at the picture below:

AB and CD are parallel segment lines, and EF is the segment line intersecting them at point G and H.

a. Based on your intuition, identify three pairs of angles that have the same degrees. Give your argumentation.

(The aim: students will be able to recognize angles that have the same size from a pair of two parallel lines intersected by another unparallel line)
Expected answer: angle AHE is the same as angle CGH, because line CD is a translated line of line AB so all angles shaped by intersecting AB to EF will always be the same all angles shaped by intersecting line CD to EF.

Therefore, two other examples are angle AHG = angle CGF, and angle EHB = angle HGD.

Approximated time to read and to answer: 5 minutes.

In this question students are asked to use their intuition and reasoning skills.

b. If you are asked to find out all degrees of angles at picture above, how many angles do you need minimally to find the other angles? Give your reason. 
(The aim: students will be able to understand that to find all unknown angles in the pictures they only need one angle known)

Expected answer: only one angle known is needed to find all unknown angles in the pictures, because by using the result of previous question it shows that if one angle can be known then other angles can be determined as well.

Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their intuition and reasoning skills.

Note:

✓ At the picture above:
  ➢ Sudut sehadap, an example of sudut-sehadap couple is angle DGF with angle BHG.
  ➢ Sudut bertolak belakang, an example of sudut-bertolak belakang couple is angle BHE with angle AHG.
- Sudut dalam berseberangan, an example of sudut-dalam-beseberangan couple is angle CDH with angle BHD.
- Sudut dalam sepihak, an example of sudut-dalam-sepihak is angle AHG with angle CGH.
- Sudut luar sepihak, an example of sudut-luar-sepihak couple is angle CGF with angle AHE.
- Sudut luar beseberangan, an example of sudut luar beseberangan is angle CGF with angle BHE.

c. For each category above, give another example of them.

(The aim: students will be able to recognize the relationship between angles)

Expected answer: the examples of

sudut sehadap: angle FGC and angle GHA,
sudut bertolak belakang: angle FGC and angle DGH,
sudut dalam berseberangan: angle DGH and angle GHA,
sudut dalam sepihak: angle BHG and angle DGH,
sudut luar sepihak: angle DGF and angle BHE,
sudut luar beseberangan: angle AHE and angle DGF

Approximated time to read and to answer: 3 minutes.

If students find difficult to answer this question, the teacher gives some clues to help students to overcome the problem.

In this question students are asked to use their intuition skill.
d. Please summarize everything you have learned from above questions as shortly as possible.

(The aim: students will be able to summarize what they have learned about relationships between angles)

Expected answer: if there are two unparallel lines intersecting, then there are two pairs of angles that have the same size. If there is a pair of parallel lines intersected by unparallel line, then only one angle should be known to determine other unknown angles.

Approximated time to read and to answer: 2 minutes.

In this question students are asked to use their reasoning skill.
Appendix E10

Activity 5 with GeoGebra for the 5th meeting

1. Draw pictures like below

2. Measure all the angles above. Then construct an angle that is formed by adding two those angles above.

3. Draw pictures like below
4. Measure all the angles above. Then construct an angle that is formed by subtracting between those angles above.

5. Draw picture like below

6. Measure all angles of the intersection lines. Drag point A and see what happen with the angles. Do the same thing to point B, C, and D.

7. What is your conclusion from the intersection between two lines?
8. Draw picture like below

9. Drag line / to the point A then measure the angle at the point A. Make a parallel line to / through point A.

10. Do the same things to point B. What is your conclusion on what you have drawn?
Appendix F1

Pre-Test

Please answer all the questions below.

Name      :
Class     :
Date      :

1. Which one of the pictures below is a line?

2. Which one of the pictures below is a pair of parallel lines?
3. Which one of the pictures below is a pair of unparallel lines?

4. Please look at the picture below.

Please write down a pair of edges which they are not parallel and they do not intersect each other?
5. Please look at again the picture at question 4. Please write down 2 angles which you can recognize.

6. Is there any relationship between an angle and unparallel lines? Please give your reason.

7. Please look at the picture below.

![Diagram](image)

a. Which one of the picture above is an equilateral triangle?
b. Did you use a ruler to measure the length of sides of each triangle, before you could say that one of them is an equilateral triangle? Or you just used your intuition to judge which one of them an equilateral triangle? Please explain your answer.

8. Please look at the picture below.

![Diagram](image)

a. Is there any pair of parallel lines in the picture above?
b. How could you recognize it, if there is any pair of parallel lines?

9. Please look at the picture below.

![Diagram with points A, B, C, D, and E, forming parallel lines and triangles.]

How many triangles can you recognize in the picture above?

Is triangle ABC equal to triangle ABD? Please give your reason.

10. Please look at again the picture at question 9.

Is angle ACB equal to angle DBC? Please give your reason.
Appendix F2

Post-Test

Name : 

Class : 

Date : 

1. Is it correct that two lines which meet at a common point must be un-parallel lines? Please give your reason.

2. Is it correct that two lines which do not meet at a common point must be parallel lines? Please give your reason.

3. What important elements must an angle have? Please give your explanation.

4. Look at the pictures below:
a. Please write down a pair of parallel lines from the pictures above. Please explain how you can say that they are parallel lines.

b. Please write down a pair of unparallel lines from the pictures above. Please explain how you can judge that they are unparallel lines.

5. Look at the picture below:

![Diagram with labeled points A, B, C, D, E, F, and G.]

a. How many angles are there that you can see or recognize at the picture above?

b. Write down three angles of some angles which you can recognize.

c. Do you see any angle which has the same size? What angles are they? How can you recognize them (using your intuition or measuring skills)
6. Look at the pictures below:

a. Before using a protractor to measure the size of angles above, Please use your intuition first to estimate how big the size of those angles.

b. Use your protractor to measure the size of each angle above. Compare both of the results (using intuition and using a protractor). Is there any difference between the two results?

c. Are you satisfied with your intuition skill? Please give your explanation about that.
7. Look at the picture below:

   ![Diagram of angles]

   a. Please group each angle into their categories (obtuse angle, acute angle, right angle, and straight angle).

   b. Please write down how you recognize each angle into their categories.
8. Look at the picture below: (Please do not use a protractor to answer this question)

a. Why can angle CEG be a complement angle to angle BFE? Please give your reason.

b. If the size of angle BEF is two times the size of angle BFE, then calculate how big the size of angle BEF and the size of angle BFE.
9. Look at the picture below (Please do not use a protractor to answer this question)

Find each size of all angles above that you can recognize and please give your argumentation how you find the solution to this question.
10. Look at the picture below:

Calculate the value of \( x \) and the value of \( y \) which are suitable to a condition of the picture above. Please give your explanation in how you find the solution to this problem.
Appendix G1

The pretest meeting (11 February 2010)

The researcher and the collaborative teacher were giving some instructions and rules in the pretest.

The students were doing the pretest.

Every student tried to do the pretest by their own work, and tried not to show their work to other students.
After the pretest was done, the researcher gave a little bit information about geogebra to the experimental class, which they would learn in the next day.
The students were looking at their pretest result before starting learning introduction of geogebra.

The researcher was giving some instructions and examples how to use geogebra.

The students were watching and listening what the researcher was showing on the wall by projector.
The students were starting learning to use geogebra by themselves.

The researcher was walking around the class to give some help and some guidance to students whom found difficult to use geogebra.

At the end of class, the researcher gave a present to each of three students whom got the best score of the pretest result.
Appendix G3

Section of students working without computer use

The researcher distributed student-answer sheets to each group. Meanwhile the questions were displayed by projector one by one.

Students were working in group, discussing and answering the questions given.
The researcher gave some explanation about the questions that students did not understand yet.

The researcher gave some help to a group that had problem to answer some questions.

*Section of students working with computer use*

The students in group were in front of computers starting to learn geometry through geogebra.
The students were asked to do some tasks that were displayed one by one on the wall by a projector.

The researcher was helping groups that had a problem to do the tasks.
Appendix G4

The second meeting (17 February 2010)

Section of students working without computer use

The researcher distributed student-answer sheets to each group. Meanwhile the questions were displayed by projector one by one.

The students were working in groups where each group had 6 members.
The researcher gave some help to a group that had problem to answer some questions.

Section of students working with computer use

The students were in front of computers working in group learning geometry through geogebra.

The researcher gave some helps to a group that faced a problem in doing the tasks.
Appendix G5

The third meeting (19 February 2010)

Section of students working without computer use

The questions were displayed one by one on the wall by a projector, and each group got the student-answer sheets.

The students were working in a small group which is only 3 members each group, and there was a group in 2, because one student did not come to school.
Appendix G6

The fourth meeting (20 February 2010)

Section of students working without computer use

The students were working in a small group, where each group was only three students.

The researcher was explaining the questions, and walking around in the class to help students.
The students were using a protractor to solve some questions.

*Section of students working with computer use*

The students were in front of computers doing their tasks through geogebra.
The researcher was giving some explanations, and helping students in doing their tasks.
Appendix G7

The firth meeting (24 February 2010)

Section of students working without computer use

The students were working on their tasks in a small group of three.

The students were using a protractor to solve some questions.
The students were using a protractor to solve some questions.

Section of students working with computer use

The students were in front of computers learning geometry through geogebra.

The researcher was helping to explain some questions that students did not understand yet.
The researcher was writing down what each group found in their investigation about size of angles through geogebra.
The students were doing the posttest.