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ANALYSIS OF HIGH SCHOOL STUDENT'S KNOWLEDGE OF RECOGNIZING EUCLIDEAN ELEMENTS

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ABSTRACT

Euclid's Elements is a work written by an ancient Greek mathematician named Euclid in the 3rd century BC. It is one of history's most famous and influential mathematical works, serving as a significant basis for studying geometry and number theory for centuries. This research aims to describe Euclid's Elements and determine the extent of high school students' knowledge about Euclid and his work and their level of understanding in solving mathematical problems. This qualitative research utilizes case study methods and literature reviews. Data were collected through problem-solving exercises and interviews. Thematic data analysis was conducted to elucidate Euclid's Elements and students' level of knowledge. The case study involved presenting mathematics problems and interviewing five high school students, using assessment instruments incorporating problem-solving and open interviews. The findings reveal that many students lack familiarity with the elements of Euclid's Elements but demonstrate proficiency in solving mathematical problems related to it.

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INTRODUCTION

Mathematics is a part of the education system that provides an important foundation for developing analytical thinking skills, problem-solving, and understanding of mathematical concepts (DEAS, 1960; Kamarullah, 2017; Susanah, 2021). In learning mathematics, people often focus on understanding concepts and applying formulas, but the historical aspects are left aside. Understanding the history of mathematics is very valuable because it will provide inspiration and perspective on why we study mathematics (Efendi, 2021; Wahyu & Mahfudy, 2016; Wahyudin & Rahayu, 2020).

One of history's most important mathematical works is The Elements by Euclid, an Ancient Greek mathematician (Akhsani, 2022; Dan & Dalam, 2021). Euclid's elements are the main foundation for learning geometry and mathematics in the educational curriculum; for example, the curriculum in Indonesia (Mauiliya, 2022; Nugraheni, 2021). This work is one of the most influential writings throughout history and has played an essential role in the development of mathematics (Susilawati, 2017; Yazidah, 2017). Euclid's Elements consists of 13 books discussing concepts and theorems in geometry, which served as a foundation for studying geometry in mathematics for centuries (Qadry, 2021; Wahyu & Mahfudy, 2016; Warmi, 2018).

By understanding the history of Euclid's Elements, students not only master geometric concepts but also develop an understanding of the origins and evolution of mathematical ideas (Kautsar, 2021; Warmi, 2018). However, teachers often forget to introduce the historical context behind the development of Euclid's Elements. This research can increase students' knowledge about the history behind the work of Euclid's Elements in mathematics education. It can combine the history of mathematics in mathematics learning in high school to enrich their overall knowledge.

One's research indicates that 58% of students understand the history of mathematics to varying degrees, with approximately 53% showing less interest in the subject. The research aims to assess the level of knowledge among senior high school students regarding the history of Euclid's Elements. It seeks to pinpoint any overlooked teaching needs and suggest improvements for future teaching approaches.

METHOD

This research adopts a qualitative approach, delving into social phenomena, human behavior, or other contexts in depth without relying on numerical data (M. Zain, 2018; Ode, 2012; Savira & Suharsono, 2013). The literature review method involves examining various documents elucidating the history of Euclid's Elements (Siswanto, 2010; Wahyudin & Rahayu, 2020). Subsequently, conclusions are drawn and meticulously analyzed to yield conclusive results aligned with the research objectives (Agustin, 2016; Ngilmaya, 2021).

In the case study, mathematics problems related to Euclid's Elements are presented to five high school students from 1 X Koto to gauge their level of understanding and identify any challenges they encounter. Below are the questions posed to the students:

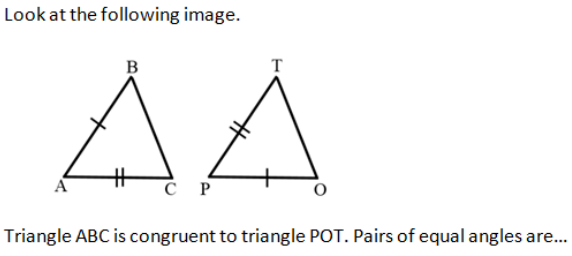

Figure 1. Question 1

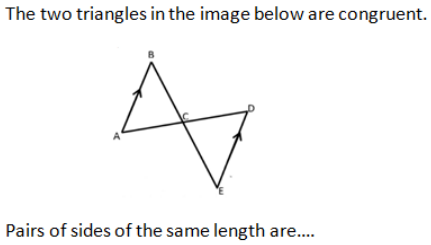

Figure 2. Problem 2

In conducting the interviews, five students from SMAN 1 X Koto participated as subjects. Among them were one male student, MR, and four female students, DW, SA, DN, and AL. The interview focused on the history of Euclid's Elements.

The following questions were posed during the interviews:

1. Have you ever heard of the name Euclid?
2. Have you ever encountered Euclid's Elements before? If yes, what do you know about it?

3. What do you think Euclid's Elements is considered an important resource for studying geometry?

RESULTS AND DISCUSSION

A. Euclid's biography

Research (Akhsani, 2022; Howard, 1969) This leads us to the conclusion that Euclid was an immensely influential philosophical figure. His mathematical insights were profoundly beneficial for the advancement of mathematical philosophy. Euclid articulated his ideas, inspiring others to expand upon them. Within three humanistic educational philosophy theories—pragmatism, progressivism, and existentialism—Euclid is a pivotal figure in the humanist tradition. His association with theories proved highly advantageous for educational and mathematical development. The study of mathematics, particularly geometry, owes much to Euclid's theories. Through his seminal work, "The Elements," and the establishment of the Five Postulates, Euclid catalyzed the development of science by showcasing his knowledge.

Research (Miller, 2007; Nugraheni, 2021) It establishes that Euclid lived around 300 BC. His renowned hypothesis, which involves creating a line segment by connecting two arbitrary points, exemplifies his mathematical prowess. The Elements, consisting of 13 volumes, stands as his magnum opus, encompassing geometry, comparison, and number theory. Despite being hailed as the father of geometry, historical accounts of Euclid are scant.

Based on research (Lutfi, 2022; Nursiwi, 2021), it's noted that "The Elements" was published in Europe in 1482. Euclid's findings amalgamate knowledge derived from luminaries such as Pythagoras, Plato, Eudoxus, and Hippocrates, rendering "The Elements" a compendium of mathematical wisdom. Structured deductively as an axiomatic system across thirteen books or volumes, Euclid's work presents statements that originate from axioms or postulates and are systematically built upon previous propositions.

The research findings (Budhi, 2015; Wahyu & Mahfudy, 2016) reveal that the fundamental achievement of the Ancient Greeks lies in Euclid's work on Axiomatic Geometry. The cornerstone of this achievement is Euclid's seminal work, "Elements," the majority of which remains pertinent today. "Elements" comprises 13 volumes, each addressing distinct mathematical concepts. The breakdown of its contents is as follows: the first book discusses the congruence of triangles, properties of parallel lines, and relationships between triangular areas and parallelograms; the second book delves into sets related to squares, rectangles, and triangles;

the third book focuses on properties of circles; the fourth book explores polygons inscribed in circles; the fifth book introduces a general theory of proportion; the sixth book expands on the congruence theory introduced in the first book; the seventh book covers properties of numerical proportions, greatest divisors, common multiples, and prime numbers; the eighth book addresses proportions in numerical progressions and squares; the ninth book presents special results, including the existence of an infinite number of prime numbers and perfect number formation; the tenth book introduces the theory of irrational lines originating from the work of Thaetetus and Eudoxus; the eleventh book discusses spatial structures; the twelfth book proves theorems concerning the ratio of circles, spheres, and volumes of pyramids and cones; and the thirteenth book explores various regular polyhedra known as Platonic solids, including the hexahedron, tetrahedron, octahedron, dodecahedron, and icosahedron.

Synthesizing insights from 10 articles on Euclid's Elements, it is evident that Euclid, an influential figure in the history of mathematics, lived around 300 BC. His magnum opus, "The Elements," spanning 13 books, encompasses a broad spectrum of mathematical topics such as geometry, comparison, and number theory. This seminal work has played a crucial role in shaping mathematical concepts and has provided a foundation for further advancements in mathematical science. Thus, it underscores the importance of comprehending Euclid's contributions to mathematical development, particularly in the realm of geometry, and the significance of understanding the history of mathematics as an integral part of human intellectual heritage.

B. Analysis of Student Knowledge

After researching five high school students, various data were obtained with different ability levels. The test question data analysis results are presented sequentially, starting from MR, SA, DW, DN, and AL. The following is an explanation of the student's answers:

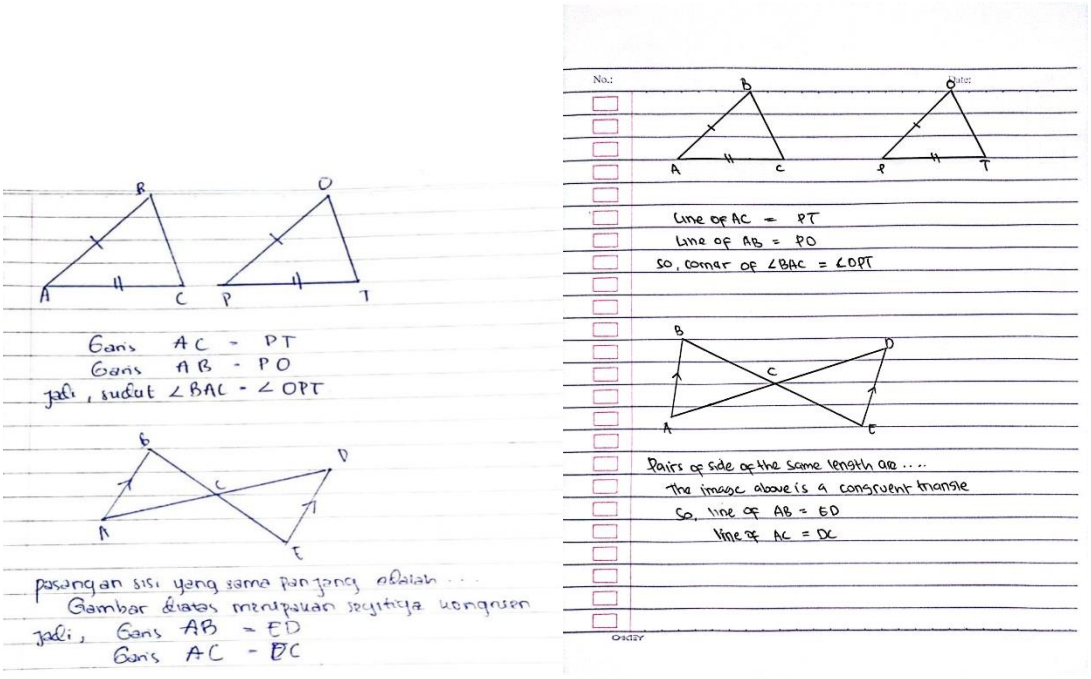

Figure 3. MR Subject Results

In Figure 3, subject MR answered both questions correctly. MR recognizes AC = PT and AB = PO as sides of equal length, given the corresponding triangles. However, MR only identifies one pair of equal angles despite there being three pairs. In the second question, MR acknowledges that AB = ED and AC = DC are of equal length but mentions only two pairs of angles: $\angle BAC \; dan \; \angle OPT$

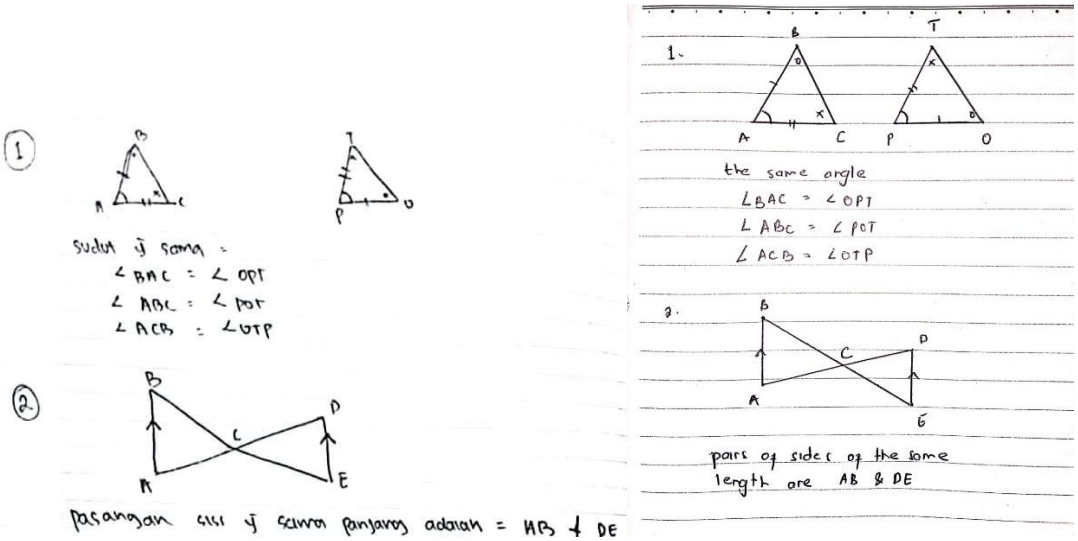

Figure 4. Results of SA Subjects

Not much different from MR's results, in Figure 4, subject SA solved the two questions. In Figure 1, subject SA could identify all three pairs of equal angles in Problem 1 and correctly marked the corresponding angles in Figure 2. For Question 2, SA recognized that AB = DE due to the matching markings but did not identify any other pairs of equal angels.

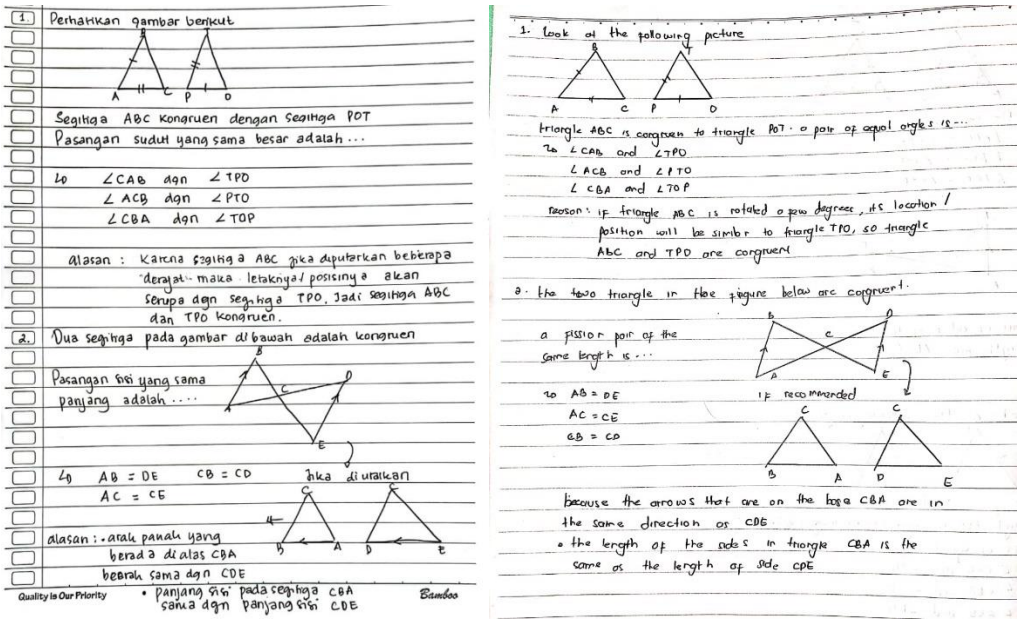

Figure 5. Subject DW Results

Furthermore, the results of subject DW, who answered both questions correctly and provided appropriate reasons to support their answers, can be seen in Figure 5. Subject DW stated that because triangle ABC, when rotated, would align with triangle TPO, this similarity implies congruence between the two triangles. In the second question, DW delineates the triangles individually. Still, in identifying the equal-length sides, an error occurs where it is stated that AC = CE and CB = CE.$\angle CAB = \angle TPO, \angle ACB = \angle PTO \; dan \; \angle CBA = \angle TOP$

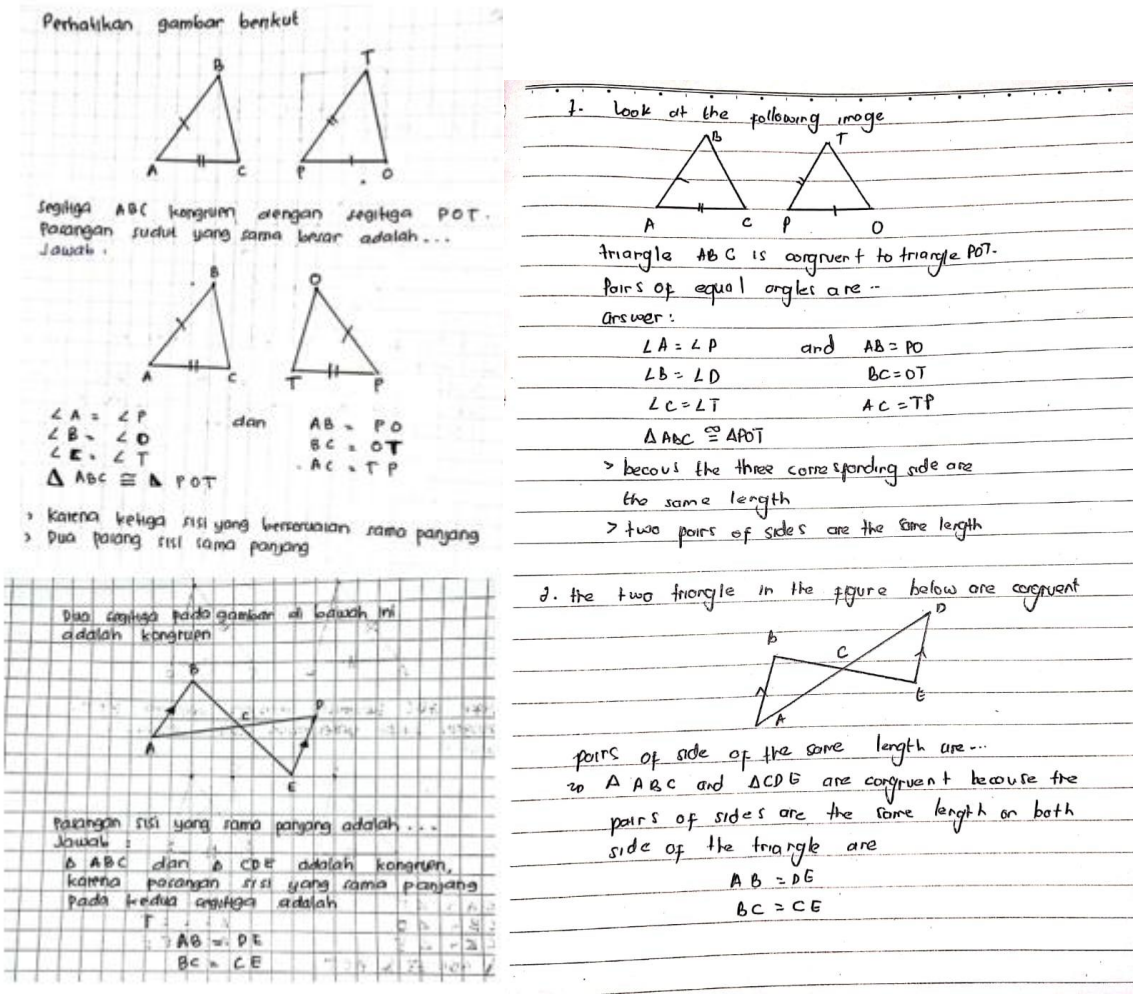

Figure 6. DN Subject Results

Subject DN also provided appropriate reasons to support their answers while working on the given questions, as evidenced by Figure 6. Subject DN identified the three pairs of angles and the three pairs of corresponding sides, thus proving the congruence of the two triangles. However, in the second question, DN only noted that the sides of equal length are AB = DE and BC = CE.

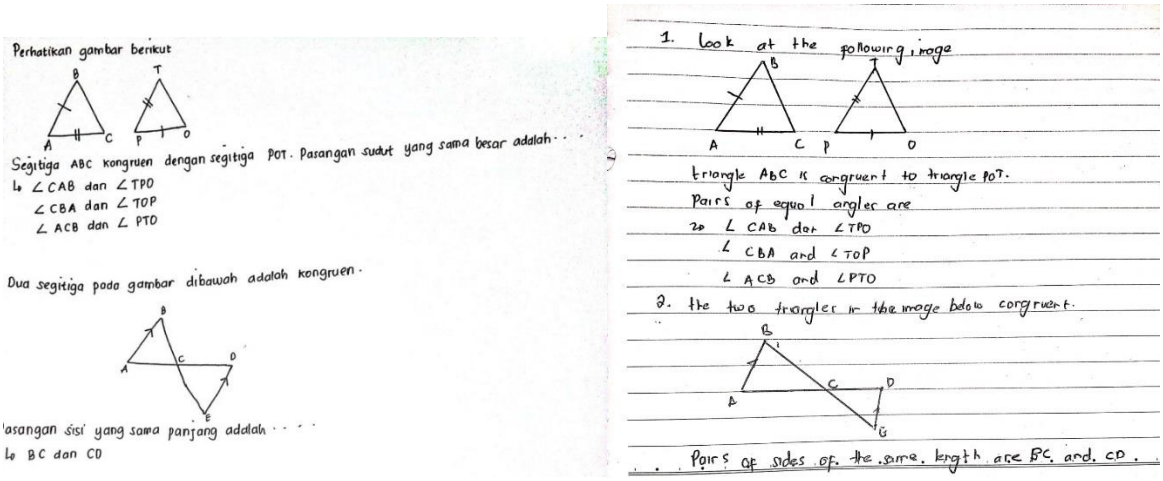

Figure 7. AL Subject Results

The final result shows that subject AL could also solve the two questions. In Figure 7, subject AL correctly identified three pairs of equal angles for the first question. However, AL made an error in the second question by stating that BC = CD, despite the correct answers being AB = DE, BC = CE, and AC = CD.

Based on the results of the data analysis above, differences are observed in the ability to solve questions and articulate opinions. This disparity suggests that female students tend to demonstrate stronger argumentation abilities than male students (Gitleman & Kleberger, 2014; Nufus et al., 2018; Salahuddin et al., 2020). Following research procedures, students are categorized based on their level of understanding, as presented in Table 1.

Table 1. Categories of Student Understanding

Comprehension Category	Description
Understand	Students have mastered the material and can accurately and precisely solve related problems.
Partially Understand	Students still lack full comprehension of the lesson, resulting in some inaccuracies when completing tasks.
Do Not Understand	Students lack understanding of the provided material. Thus, they are unable to solve related problems.

Table 2 shows the grouping of students based on their level of understanding of the questions given, where the categories are explained in Table 1.

Table 2. Grouping of Students' Knowledge Categories

Knowledge Category	Understand	Partially Understand	Do Not Understand
Student	DW, MR, DN	SA, AL	

The level of student's knowledge regarding Euclid's Elements is categorized into 3 categories: Knowing, less knowing, and Unfamiliar. Therefore, we will discuss the findings of previous research.

Understand

This category includes students who understand and have mastered the material or subject well. They can clearly explain key concepts and relate them to their existing knowledge. These students can effectively respond to questions (Kusuma, 2014; Yazidah, 2017).

Partially Understand

A category consisting of students who do not understand the basic concepts. They may need additional help or deeper explanations. Students may feel confused or need to learn more about this topic (Aaliyah & Uyun, 2022; Warmi, 2018).

Do Not Understand

The category includes students who do not understand the material or topic at all, or whose understanding is minimal. They cannot explain the concepts, and the material seems unfamiliar. These students require primary teaching and guidance to grasp the content. (Sholihah, 2021; Handayani, 2021).

The results of the interview data analysis are presented sequentially, starting with male subjects (MR) and female subjects (DW). Firstly, Subject MR doesn't know about Euclid but has studied geometry at school. We can review the results of the following interview:

Researcher: Good afternoon! Today, we will discuss Euclid's Elements. Have you ever heard of Euclid's?

MR: Good afternoon! I've never heard of Euclid's Elements. What is that?

Researcher: OK, Euclid's Elements is one of the famous works in geometry. Euclid was an Ancient Greek mathematician who wrote the book, one of the oldest mathematical works still in existence.

MR: I don't know yet, but I have studied geometry at school. What are Euclid's?
Researcher: Euclid contains axioms, definitions, and theorems in geometry, which is the basis of geometry. If you have studied geometry, most of Euclid's elements are lines, angles, triangles, etc.
MR: So, what makes Euclid an essential source in studying geometry?
Researcher: Euclid's are important because they organize geometric concepts and provide a basis for proving mathematical theorems in geometry.
MR: Thank you for the explanation. How can teaching Euclid be more engaging for students who already know geometry?
Researcher: Teaching Euclid by relating them to real-world examples. For example, game design or area mapping shows that mathematical concepts are used in life.
MR: One of the exciting teachings.
Researcher: Yes, so don't be afraid to study Euclid and continue to increase your knowledge.
MR: OK. I will try to go deeper into Euclid's.

Furthermore, the results of interviews with DW subjects who knew more or less about Euclid's Elements but did not know more in-depth, which can be seen from the following interview:

Researcher: OK, today we will discuss Euclid's Elements. Have you ever heard of it?
DW: Yes, sis. I've heard about it, but I know only a little about Euclid's.
Researcher: OK, that's good. Do you know who Euclid is?
DW: Euclid was a mathematician known as the father of geometry.
Researcher: So, what do you know about Euclid's?
DW: Euclid is a book that contains concepts such as lines, angles, and others.
Researcher: Good. Do you think it is important for today's high school students to learn about Euclid's Elements?
DW: I think Euclid's are still important because we learn many of the basics of geometry in mathematics. Understanding how Euclid developed geometric concepts helps us know the basics of geometry better.

Researcher: Well, that's right. Our understanding of Euclid needs to be improved. Apart from that, Euclid also teaches how to think logically and prove mathematical theorems. Next, how can Euclid be enhanced to make it more attractive to high school students?
DW: providing examples from everyday life makes it more attractive for students to understand.
Researcher: Well, that's a good approach. You have provided good insight into Euclid's and further improved your understanding of Euclid's.
DW: OK.

Based on the results of the data interview above, students can be categorized based on their level of knowledge about Euclid's Elements, shown in Table 3.

Table 3. Categories of Student Knowledge

Knowledge Category	Description
Knowing	The students in the research sample are in the knowing category, indicating that they understand Euclid's Elements well. They may have studied or been exposed to the concept of Euclid's Elements before and are knowledgeable about this topic.
Less Knowing	This suggests that students who fall into the category of less knowing do not have sufficient understanding. It implies that the sampled students have a minimal grasp of the topic.
Unfamiliar	Students fall into the unfamiliar category, indicating that students in the research sample have limited understanding or do not know about Euclid's Elements.

Table 4 will show the grouping of students based on the three categories explained in Table 3.

Table 4. Grouping of Students' Knowledge Categories

Knowledge Category	Knowing	Less Knowing	Unfamiliar
Student	DW		MR, SA, DN, AL

The level of student's knowledge regarding Euclid's Elements is categorized into three categories: Knowing, less knowing, and Unfamiliar. Therefore, we will discuss the findings of previous research.

Knowing

This category includes students who have a good understanding of Euclid's Elements. In this study, only a few people knew about Euclid's Elements. They may have been exposed to the concept of Euclid's Elements before, either in math lessons or through additional learning (Suyitno, 2012; Suryaningtyas & Setyaningrum, 2020). Students in this category can confidently explain the concept of Euclid's Elements and apply its principles to geometric problems such as axioms, definitions, and geometric theorems (Dan & Dalam, 2021; Yazidah, 2017). They have a strong knowledge of these concepts and can likely apply them in further mathematical contexts (Siswono, 2007; Wahyu & Mahfudy, 2016).

Less Knowing

The lack of knowledge category indicates that students do not understand Euclid's Elements in the research sample. None of the samples fall into this category. All students have at least a basic understanding or knowledge of this topic, which can be the basis for further learning (Argaswari, 2018; Siswono, 2007).

Unfamiliar

This category includes students in the research sample who have limited understanding or do not yet know about Euclid's Elements. This suggests that most of the students in the study sample needed a basic understanding of this topic They may have never been exposed to the concept of Euclid's Elements before or require additional learning to understand it (Argaswari, 2018; Multimedia, 1996). Because most of the students in the study fall into this category, further efforts need to be made to learn and understand Euclid's Elements among students.

This discussion can be used as a basis for planning to increase students' understanding of Euclid's Elements. The results from Table 4 show potential improvement in learning and understanding of Euclid's Elements among high school students.

CONCLUSION

Euclid's Elements is one of history's most important mathematical works, written by the ancient Greek mathematician Euclid in the 3rd century BC. This work contains the concepts of geometry, comparison, and number theory, which have been the main basis for studying geometry and number theory for centuries. Learning and understanding the concept of Euclid's Elements is important to improve and relate it to real-world examples. The research aims to determine the extent of students' understanding of the character Euclid and his work, Euclid's Elements. Based on research, three categories of students can be created regarding Euclid's Elements: Knowing, Less Knowing, and Unfamiliar. Three types of students are also assessed based on their level of understanding, namely Understand, Partially Understand, and Do Not Understand.

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