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COMMOGNITIVE AND LEARNING STYLES STUDY OF STUDENTS' MIDDLE SCHOOL UNDERSTANDING OF CIRCLES

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ABSTRACT

Understanding of mathematical concepts, especially in circle material, is influenced by students' learning styles and the way they communicate in solving problems. This study aims to analyze how students with visual, auditory, and kinesthetic learning styles apply the commognitive component in solving circle problems. The research method used is a qualitative approach with data collection techniques in the form of observation and interviews. The subject of this research is at public middle school 51 Makassar. The main instruments in this study include learning style questionnaires, written tests, and interviews. The data analysis technique includes three main stages: data reduction, data presentation, and conclusion drawing. To ensure data validity, this study used triangulation techniques and sources. The results indicated that students with a visual learning style used more visual mediators and words to understand the concept of a circle. Students with auditory learning styles tend to rely on narration in explaining concepts and are more fluent in oral communication, while students with kinesthetic learning styles use more routines and hands-on practice in solving problems. The conclusion of this study confirms that each learning style has a different tendency to utilize the commognitive component. Therefore, the optimal learning strategy should accommodate various learning styles so that students' understanding of mathematics concepts is more effective and meaningful.

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1. INTRODUCTION

Mathematics as a scientific discipline has abstract characteristics that often make students have difficulty in understanding basic concepts (Lerman, 2020; Syahri et al., 2024). One of the essential branches of mathematics that requires in-depth understanding is geometry, especially circle material, which includes various elements such as radius, diameter, circumference, and area (Depdiknas, 2006). Understanding circle concepts is not only important in academic contexts but also in everyday life, such as in engineering and architecture. However, many students still experience difficulties in applying the concept, especially in solving problems that require in-depth analysis

(Fitri & Aima, 2017; Nilimaa, 2023; Verschaffel et al., 2020). Differences in students' learning styles can exacerbate this difficulty by affecting how they absorb and process mathematical information (Wan Hussin & Mohd Matore, 2023). Learning styles are divided into visual, auditory, and kinesthetic, each of which has a unique way of understanding the material being taught (Fallace, 2023; Setyadi et al., 2020).

One approach that can be used to understand student difficulties in mathematics is the commognitive theory (Sfard, 2020; Shinno & Fujita, 2022). This theory combines aspects of "communication" and "cognition," emphasizing that thinking in mathematics is a form of communication that develops through social interaction and the use of appropriate mathematical language (Kim et al., 2017; Sfard, 2020). In this approach, there are four main components that make up mathematical communication, namely word use, visual mediation, narrative, and routine (Cooper & Lavie, 2021; Mpofu & Pournara, 2018). These four components not only assist students in understanding mathematical concepts more deeply but also enable learners to communicate mathematical ideas more clearly and systematically. In the context of circle learning, utilizing commognitive theory can help identify how students with different learning styles use different aspects of communication in understanding mathematical concepts. By understanding how cognitive components interact with students' learning styles, educators can develop learning strategies that are more effective and appropriate to students' needs, thus improving students' understanding in solving mathematical problems more optimally.

Learning style is an important factor that affects how students process and understand information in the learning process (El-Sabagh, 2021; Schulze & Bosman, 2018). According to learning style theory, there are three main types of learning styles, namely visual, auditory, and kinesthetic, each of which has a unique way of absorbing and processing information (Giardina, 2025; Zagoto & Dakhi, 2018). Students with visual learning styles find it easier to understand concepts through pictures, diagrams, and writing because learners are better able to connect abstract information with concrete visual representations. In learning circle material, for example, visual students will be helped by illustrations of circle shapes, the use of colors, and symbols that distinguish important elements such as radius and diameter (Nurdyasnyah & Andiek, 2015).

In contrast to visual students, students with an auditory learning style find it easier to understand concepts if the material is delivered in the form of oral explanations or group discussions (Knoll et al., 2017). Students are better able to absorb information through lectures, discussions, or sound recordings than by reading or looking at pictures (Rambe & Yarni, 2019). In learning circles, auditory students will better understand the material if the teacher uses an interactive discussion method, where students can hear as well as talk about the concepts being learned (Azizah & Widyartono, 2024). However, students may have difficulty in understanding diagrams or symbols without a clear verbal explanation. Therefore, in the cognitive approach, the narrative component is a major factor in supporting the understanding of students with auditory learning styles.

Students with kinesthetic learning styles have a tendency to understand material by doing physical activities or hands-on practice (Sulisawati et al., 2019; Zagoto & Dakhi,

2018). Students learn more easily through direct experience, such as holding, drawing, or making models (Danişman & Erginer, 2017). In circle learning, kinesthetic students understand concepts better if given props such as folding paper, three-dimensional circle models, or direct exploration activities in the surrounding environment (Yusuf & Amin, 2016). However, (Ruswana & Zamnah, 2018) suggest that students may struggle to comprehend information solely through written or verbal means without any real-world experience to support it. Therefore, in the cognitive approach, the use of routines or procedures involving exploratory steps becomes an important aspect in supporting kinesthetic students' understanding.

Several studies have indicated that learning styles have a significant effect on students' understanding of mathematics, especially in solving geometry-based problems (Danaryanti & Noviani, 2015; Firmanti et al., 2024; Zales & Vasquez, 2022). Understanding the concept of a circle does not only depend on students' ability to memorize formulas but also on how students communicate mathematical thinking in solving problems (Setyadi et al., 2020). Studies show that students who learn with methods that suit their learning styles tend to have better understanding and are able to solve problems more effectively compared to students whose teaching methods do not match their learning preferences (An & Carr, 2017; Cardino Jr & Cruz, 2020; Rambe & Yarni, 2019). In this case, the commognitive approach can be an appropriate strategy in analyzing how students with different learning styles understand and communicate circle concepts in mathematics learning (Kim et al., 2017; Sfard, 2020). Therefore, a more flexible and adaptive learning approach is needed to accommodate various learning styles of students and increase the effectiveness of understanding mathematics concepts (Eka Afri et al., 2022; El-Sabagh, 2021; Setyadi et al., 2020).

A preliminary study by the author found that students have different ways of understanding and solving circle problems, based on interviews with mathematics teachers in grade VIII of the public middle school 51 Makassar. Some students have difficulty determining the steps in solving story problems due to a lack of understanding of the formulas and basic concepts of circles. When it comes to addressing story issues, some pupils struggle because they don't grasp the fundamentals of circles and their formulas (Demir et al., 2023; Diana et al., 2020; Sheromova et al., 2020). This shows that learning style factors play an important role in determining how students understand and solve mathematics problems, especially in circle material. Based on the description above, this study aims to analyse students' cognitive in understanding circle material based on learning style. This research is expected to provide insight into how commognitive components interact with students' learning styles, so that it can be used as a basis for developing more effective and inclusive learning methods in learning mathematics. By understanding the relationship between commognitive and learning styles, teachers can develop more adaptive learning strategies, so that each student can understand mathematical concepts in a way that suits their learning characteristics. Therefore, this research is expected to be a contribution to improving the quality of mathematics learning, especially in the field of geometry, which is often considered difficult by students.

2. METHOD

This research uses a descriptive qualitative method, which aims to describe students' cognition in understanding circle material based on learning style. This method was chosen because it is able to explore in depth how students with different learning styles (visual, auditory, and kinesthetic) communicate their thought process in solving circle problems. The qualitative approach helps researchers see the big picture by focusing on how students communicate mathematically through words, visual aids, stories, and regular practices.

This research was conducted at public middle school 51 Makassar, with the research subjects being as many as three class VIII students who were selected based on the results of the learning style questionnaire. One student, who demonstrated a dominant tendency towards a particular learning style, represented each learning style (visual, auditory, and kinesthetic). The sampling technique used was purposive sampling, which allows researchers to select subjects that are in accordance with the research objectives (Sugiyono, 2017). Thus, the data obtained can provide a more specific picture related to students' cognitive patterns in solving mathematics problems, especially in circle material.

The main instruments in this study consisted of learning style questionnaires, written tests, and interviews. We used the questionnaire to determine students' learning styles based on visual, auditory, and kinesthetic categories. The written test was given to identify how students solve mathematics problems using the commognitive component, while interviews were used to dig deeper into students' thought processes when solving issues. The collected data were then analyzed using the Miles & Huberman (1994) data analysis technique, which includes three main stages: data reduction, data presentation, and conclusion drawing.

To ensure data validity, this study used triangulation techniques and sources. Technical triangulation involved looking at results from questionnaires, written tests, and interviews, while source triangulation involved checking if students' answers matched up through detailed interviews and confirmation from mathematics teachers (Creswell, 2018). By using this approach, the research results are expected to provide a more accurate understanding of how learning styles affect the way students understand and communicate the concept of circles in mathematics learning

3. RESULTS AND DISCUSSION

Based on the research results, each learning style has a different tendency in using the cognitive component. The following is a more detailed explanation of how students with visual, auditorial, and kinesthetic learning styles apply cognitive in understanding the concept of circle:

Commognitive Students with Visual Learning Styles

The results of the work of subjects with visual learning styles in solving problems using commognitive components, namely the use of words, visual mediators, narratives, and routines. The results of the work can be seen in Figure 1.

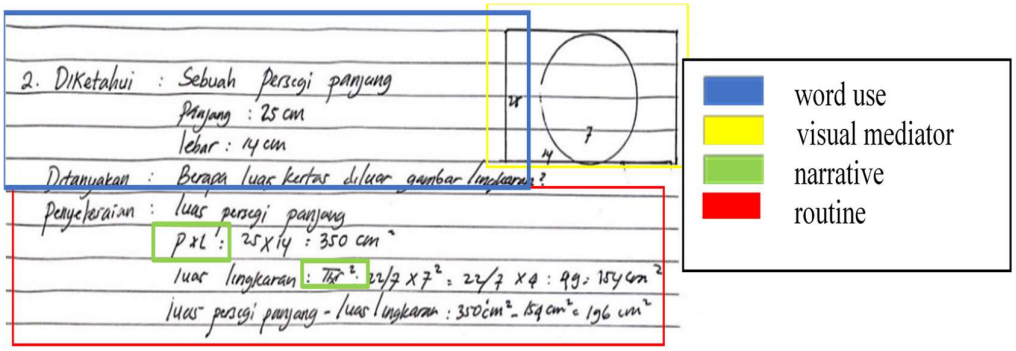

Figure 1. The work of subjects with visual learning styles

Subjects with visual learning styles in solving circle problems apply commognitive components, which include the use of words, visual mediators, narratives, and routines. In identifying information from the problem, the subject used terms such as 'circle diameter' and 'circle trajectory' to understand and organize information clearly and logically. This finding is relevant to the research of Setiana et al. (2021), which shows that subjects with visual learning styles are able to record known information and questions in problems accurately, completely, and efficiently. In addition, the subject also used visual mediators in solving the circle problem by drawing a circle as a representation of the problem given. The use of this image helps students understand the concept better, because students with visual learning styles more easily capture information in the form of graphical representations. This conclusion is supported by research by Yuliana (2024), which states that students with visual learning styles tend to use visual elements such as colours, patterns, and shapes to understand a concept more effectively.

In solving the problem, the subject also applied the commognitive component in the form of narration, especially in the proper use of the circumference formula. The subject wrote the formula and provided an explanation for its application in solving the problem. Research supports this assumption Firdaus (2023), which found that students with visual learning styles tend to explain the reasons at every stage of problem solving, so that students' mindsets are more structured. Meanwhile, in the routine aspect, the subject wrote down the steps of the solution coherently and in detail to ensure that the answer obtained was in accordance with the information available on the problem. Research by Setiana et al. (2021) also stated that subjects with visual learning styles were able to arrange the steps of the solution appropriately so that the conclusions produced were more relevant and detailed.

However, although subjects with visual learning styles can explain the four cognitive components systematically and in detail, students experience problems in verbal communication. When explaining his thought process, the subject seemed nervous and confused. Students with visual learning styles often struggle to express their thoughts verbally, particularly during discussions or interviews.

Commognitive Students with Auditorial Learning Styles

The study examines how subjects with auditory learning styles solve problems using commognitive components, such as words, visual mediators, narratives, and routines. Figure 2 displays the outcomes of the work.

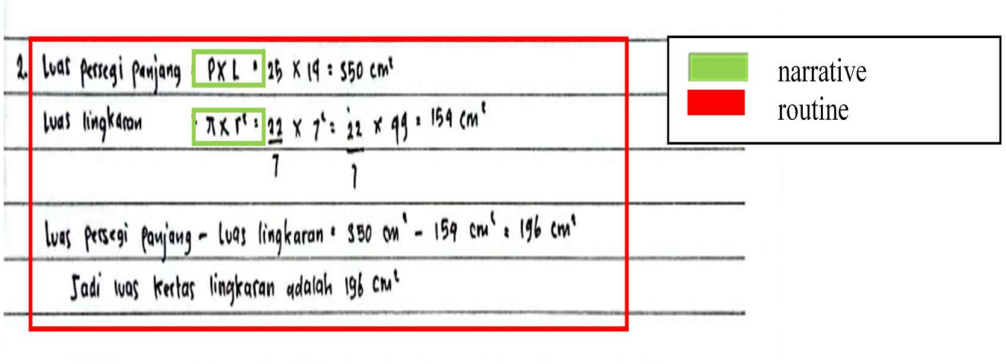

Figure 2. The work of subjects with auditory learning style

Subjects with auditory learning styles in solving problems apply several cognitive components, namely narratives and routines. However, this subject did not employ the other two cognitive components, namely the use of words and visual mediators. The subject did not explicitly write down the known and questionable information about the problem but only noted the parts that were considered important. In addition, the subject did not use visual mediators in problem solving because he was not used to representing problems in the form of drawings or sketches. This difficulty in imagining a concept visually is in accordance with the findings of Han (2022), who stated that students with auditory learning styles are less skilled in sketching problems and rely more on verbal understanding through hearing.

In organizing information about the problem, subjects with an auditory learning style wrote it briefly without including all the details. This behavior is in line with the research of Yulianci et al. (2020), which states that students with an auditory learning style tend to only record information that learners consider important. In preparing the solution plan, the subject effectively used relevant circle formulas like those for calculating area and circumference. Despite presenting the solution in a more concise form than other learning styles, it remains systematic. Subjects with an auditory learning style tend to write down the steps of problem-solving directly and not wordily, only listing the stages that are considered important. In line with research by Troussas et al. (2025), students with auditory learning styles prefer listening activities over writing, so students often abbreviate or skip some steps that learners think are not critical in problem solving.

Although subjects with an auditory learning style minimally record information, students are still able to explain the information learned from the problem and the questions given clearly and completely. In addition, the subject can describe the steps of the process coherently from beginning to end eloquently. It is stated that students with an auditory learning style tend to be good speakers, easy to discuss, and more comfortable explaining concepts orally rather than writing them down in detail.

Commognitive Students with Kinesthetic Learning Styles

The results of the work of subjects with kinesthetic learning styles in solving problems using commognitive components, namely the use of words, visual mediators, narratives, and routines. The results of the work can be seen in Figure 3.

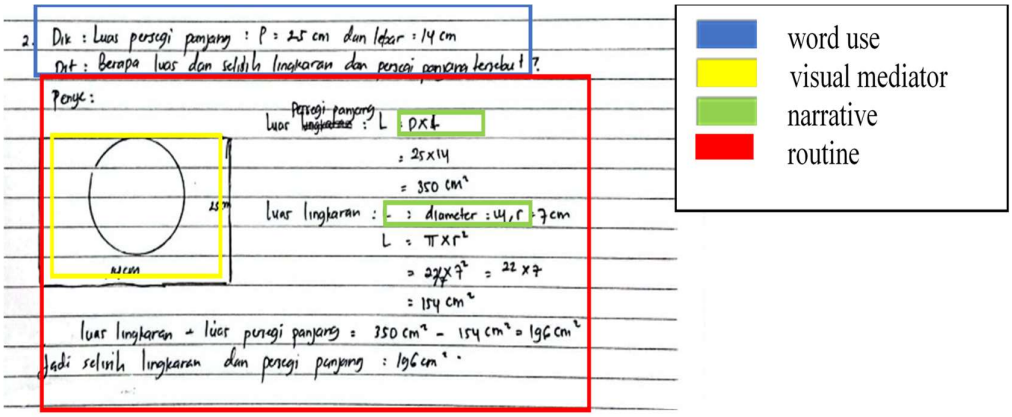

Figure 3. The work of subjects with Kinesthetic learning style

In mathematical problem solving, subjects with kinesthetic learning styles show similarities with visual learning styles in several aspects. Students recorded the known and questionable information in the problem briefly in their words, although there were some who did not write it explicitly. This conclusion is in accordance with the findings of Setiana et al. (2021), who stated that students with kinesthetic learning styles tend to present information in a simpler form and in their language, although occasionally it is less clear to the reader. In solving circle problems, this subject applies to the commognitive component in the form of using words, both orally and in writing, in a simpler form. Additionally, students often rehearse the teacher's explanations by visualizing the problem. This habit demonstrates students' accustomed use of visual illustrations as a tool for understanding and solving mathematical problems. In line with research by Apipah (2018), subjects with kinesthetic learning styles find it easier to understand concepts when they see teachers practicing them directly, which helps students solve problems more quickly.

Another cognitive component used by subjects with a kinesthetic learning style is narration, especially in the application of circle formulas such as circle area and circle circumference. The subject wrote down and applied the formulas correctly in solving the given problem. Although the solution steps that students make are correct and systematic, student writing tends to be less neat and not so structured. Research by Troussas et al. (2025) supports this finding, stating that students with kinesthetic learning styles tend to have less organized writing. In addition, subjects with kinesthetic learning styles show the use of cognitive components, specifically routines, in solving problems in a detailed and sequential manner. Students can point out in detail the stages of completion, starting from the initial steps to obtaining the result, although the student's explanation focuses more on the main points than a long description. During the working process, this subject also shows typical habits such as moving their hands or pointing to the student's work when writing known and questionable information.

When interviewed, the subject with a kinesthetic learning style was able to reexplain the steps that had been done well, although he used more body movements to support his explanation. This states that students with kinesthetic learning styles often use fingers as pointers when reading and make many body movements when speaking or explaining concepts. Thus, the characteristics of kinesthetic learning styles that emphasize direct experience and physical activity can be an important factor in designing learning strategies that are more effective and appropriate to students' needs (Ma & Ma, 2014).

Tabel 1. Conclusion of Commognitive Comparison on Three Learning Styles

Commognitive Component	Visual	Auditorial	Kinesthetic
Word use	Uses mathematical terms in writing, but lacks in verbal communication	Excels in explaining concepts orally, but sub-optimal in writing them down	Good with physical activity, but weak in verbal or written explanations without practice.
Visual mediator	Rely heavily on diagrams, graphs and illustrations	Rarely uses diagrams, relying more on verbal descriptions	Prefer to use props or real objects
Narrative	Tends to be stronger in writing down answers but lacks in explaining verbally.	I am very good at explaining concepts verbally.	Less comfortable explaining concepts without hands-on practice
Routine	Uses systematic and image-based solution strategies	Repeats concepts frequently through discussion or talking with friends	Practising concepts with physical activities or manipulation of props

Building upon the results of this study, each learning style has a unique cognitive pattern. Students with visual learning styles rely more on visual mediators, students with auditory learning styles are more prominent in narration, and students with kinesthetic learning styles rely more on physical activity-based routines. Therefore, an optimal learning approach should accommodate all cognitive components according to students' learning styles (Khamparia & Pandey, 2020; Sfard, 2020). In learning mathematics, especially in circle materials, teachers can develop more effective teaching methods by combining strategies that are suitable for each learning style. For example, for visual students, teachers can use more image media or animated videos; for auditory students, teachers can apply group discussions or interactive lectures; while for kinesthetic students, teachers can apply hands-on practice with props or exploratory activities (Setyadi et al., 2020). Thus, differences in student learning styles can no longer constrain the optimal understanding of the circle concept for each student.

The benefits of this research are expected to make a real contribution to the development of mathematics learning strategies that are more adaptive to students' learning styles. This study's results could help create better and more engaging learning

experiences, especially in geometry topics like circles, by combining the commognitive method with different learning styles (visual, auditory, and kinesthetic).

4. CONCLUSION

Students who learn visually usually solve problems in an organized and detailed manner by using four key elements: words, visual aids, stories, and routines. When they note down what they know and what the problem asks, they use clear and structured language to make it easier to understand. Students use clear and structured language when recording known information and problem questions to enhance understanding. In addition, students utilize visual mediators by describing problems in the form of sketches or diagrams, because visual representations help learners remember and understand concepts better. The student also chose the appropriate narrative with the circle formulas and applied it appropriately so that the routine in the solution steps could be carried out coherently and correctly. However, the subject had difficulty in explaining the process that had been done verbally, because students are more comfortable pouring thoughts into writing than oral communication.

Students with an auditory learning style solve problems using two cognitive components, namely narratives and routines, by only recording information that is considered important. In solving the problem, the student used narratives in the form of circle and rectangle formulas appropriately so that the solution steps could be done correctly and systematically. The routine applied by the student can be seen in the sequence of steps taken in solving the problem, although the quality of the student's writing is not as structured as that of visual students. In addition, auditory students have difficulty making sketches or visual representations of problems because they are more comfortable solving them without the help of images. Nevertheless, an auditorial student can explain the solution process orally very well because pupils have fluent and clear speaking skills.

Additionally, students with kinesthetic learning styles solved the problem using all four components of commognitive, namely the use of words, visual mediators, narratives, and routines. In recording the information obtained from the problem, the subject utilized the word component to write it down in his language style. In addition, the subject used visual mediators to represent the problem in the form of a circle drawing, although the results were less detailed and less neat. In the narrative aspect, the students applied the circle formula correctly to solve the given problem. Kinesthetic students were able to explain in detail the sequence of work from the beginning until they got the result, although they only emphasized the main points. The students often use hand gestures, like pointing to the results, to clarify the process during the interview. The study indicates that kinesthetic students are more comfortable conveying their thoughts through physical activity than only by writing or speaking without supporting movements.

As a suggestion, teachers and educators can combine the cognitive approach and learning style preferences (visual, auditory, and kinesthetic) for designing more effective, communicative, and meaningful learning, especially in geometric materials such as circles. We suggest not only further research into the material but also expanding its scope

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