

Analysis of the Use of Artificial Intelligence on Students' Critical Thinking Skills in Trigonometric Ratios

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ABSTRACT

This study aims to analyze how the use of artificial intelligence affects the critical thinking skills of tenth-grade students on the topic of trigonometric ratios at SMK Wikrama 1 Jepara. This study employs a descriptive qualitative approach involving 22 students divided into five groups. Data were collected through written tests based on five indicators of critical thinking (identification, justification, inference, clarification, and strategy formulation), in-depth interviews, and documentation of students' interactions with artificial intelligence. Data analysis was conducted using the interactive analysis model proposed by Miles and Huberman. The results indicate that students' critical thinking skills are categorized into three levels: high, moderate, and low. Students with high-level abilities utilize artificial intelligence as a dialogic partner to deepen their conceptual understanding and independently verify their answers. Students with moderate abilities use artificial intelligence as an additional source of information. Meanwhile, students with low abilities tend to copy answers without engaging in critical reasoning processes. These findings suggest that the effectiveness of artificial intelligence in supporting critical thinking largely depends on how it is used, rather than merely on access to it.

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INTRODUCTION

Artificial intelligence has become a global phenomenon that significantly transforms how people learn across various countries. The OECD (2023) reports that several developed countries, such as Finland, South Korea, and Japan, have integrated artificial intelligence to support personalized learning, particularly in science and mathematics. Tulak et al. (2024) demonstrate that the implementation of artificial intelligence in Eastern Europe has significantly improved mathematics learning outcomes through adaptive assessment that adjusts the level of difficulty in real time based on students' abilities. Gleneagles et al. (2024) report that Singapore and China have implemented artificial intelligence-based techniques to enhance students' critical thinking and problem-solving skills in a structured manner. These findings indicate that artificial intelligence, as an effective educational strategy, has transformed learning paradigms to become more flexible, efficient, and responsive to individual students' needs across different countries.

In Indonesia, the use of artificial intelligence in education has also begun to develop. Srianti et al. (2025) report that artificial intelligence successfully improves the understanding of basic mathematical concepts through instant and interactive feedback. Dinata et al. (2025) state that artificial intelligence supports teachers in conducting diagnostic evaluations of students' learning difficulties efficiently. Meanwhile, Alamsyah (2025) emphasizes that artificial intelligence makes the learning process more reflective and adaptive through automated feedback that is relevant to the learning context. Agustinasari and Fiqry (2025) add that artificial intelligence can enhance interactivity, critical thinking, and analytical skills in mathematics learning. Harmilawati et al. (2024) further state that, through data-driven dialogue, artificial intelligence can help students understand concepts and critically analyze information when used appropriately and accompanied by guidance that encourages active cognitive engagement.

However, there are challenges in the use of artificial intelligence in mathematics learning, particularly concerning critical thinking skills. Firdaus and Firman (2023) argue that most students tend to use artificial intelligence merely as a tool to obtain quick answers without engaging in systematic reasoning. Ramadhan et al. (2025) suggest that many students are not yet capable of critically interpreting information generated by artificial intelligence systems. Raitskaya and Tikhonova (2025) add that human–artificial intelligence interaction has an ambivalent nature; if users are not taught to manage their cognitive processes, such interaction may lead to cognitive dependency, which is counterproductive. Ratnawati et al. (2024) found that although students are able to solve mathematical problems with the assistance of artificial intelligence, they often lack understanding of the underlying conceptual processes. The topic of trigonometric ratios, which is abstract and requires high-level analytical skills, becomes a highly relevant context to examine this phenomenon, as Fajri and Nida (2019) and Kamalia et al. (2020) both report that students experience significant difficulties in understanding conceptual relationships among trigonometric elements.

A review of the literature indicates that research on the synchronization between vocational high school students' interaction patterns with artificial intelligence and the quality of their actual answers in trigonometric ratios has not yet been conducted. Previous studies, such as Ratnawati et al. (2024), which examined ChatGPT among university students in analytic geometry, Fitri et al. (2025), which investigated trigonometric identity proofs in higher education, and Brazao and Tinoca (2025), which used educational chatbots in general case studies, have all focused on higher education levels or different aspects. Walter (2024) emphasizes that artificial intelligence literacy and critical thinking skills must be developed simultaneously so that students become intelligent users of technology. However, studies examining how the synchronization between ChatGPT responses and students' actual answers reflects different levels of critical thinking remain very limited. Therefore, this study aims to fill this gap by conducting a qualitative study that analyzes the synchronization between ChatGPT conversations and the actual answers of tenth-grade students at SMK Wikrama 1 Jepara across each indicator of critical thinking in trigonometric ratios. This study is expected to provide an operational understanding of how artificial intelligence technology influences critical thinking processes in a concrete and measurable way.

LITERATURE REVIEW

This study is grounded in two main learning theories that are relevant to the context of artificial intelligence-based learning, namely constructivism and Problem-Based Learning (PBL). Constructivist theory, developed by Piaget and Vygotsky, emphasizes that students actively construct their own knowledge through experience, reflection, and interaction with the learning environment. In the context of artificial intelligence, this principle positions

technology as a tool that facilitates students' knowledge construction processes. Samaray (2025) explains that artificial intelligence, such as ChatGPT, can act as an intellectual collaborator that helps students independently construct logical reasoning in mathematical problem-solving processes, which aligns with constructivist principles of active and reflective learning. Buton et al. (2025) add that the implementation of ChatGPT in mathematics learning helps students learn independently and interactively, as it can adapt explanations to their evolving levels of understanding.

Problem-Based Learning (PBL) theory places students at the center of the learning process through contextual and challenging problem-solving activities. PBL aims to develop critical thinking skills, problem-solving abilities, and independent learning through students' active participation in analyzing, seeking information, and collaboratively finding solutions. Suryaningrat et al. (2025) state that the integration of artificial intelligence and PBL creates a collaborative learning environment that promotes critical thinking, as artificial intelligence provides adaptive informational resources that support students' investigative processes. Zaini et al. (2024) found that the integration of artificial intelligence in learning can enhance analytical skills and students' ability to evaluate the accuracy of information, which are core competencies of PBL. In the context of trigonometric ratios, a PBL approach supported by artificial intelligence enables students to engage with contextual problems that simulate real-life situations, such as calculating the height of buildings or determining slopes, thereby fostering critical thinking in meaningful contexts.

Critical thinking in mathematics learning is a fundamental competency that encompasses various cognitive dimensions. Aminudin and Basir (2019) define critical thinking skills as the capacity to evaluate accurate information, verify the validity of ideas, and assess the necessary steps to solve problems rationally based on logical considerations. Setyawan et al. (2021) state that critical thinking is a mental process aimed at understanding, evaluating, and constructing mathematical knowledge logically and responsibly, and it becomes an essential component in artificial intelligence-based learning. Yazidi (2023) adds that critical thinking skills also include the ability to evaluate relationships among concepts and identify effective patterns of thinking. Andayani et al. (2024) explain that the critical thinking process enables students to review solution steps and avoid logical errors, particularly in advanced mathematical topics that require multi-step reasoning. Critical thinking skills and mathematical thinking are closely correlated, as both require logical analysis and systematic deductive reasoning.

This study operationalizes critical thinking through five indicators adapted from the literature. First, identification, which refers to the ability to recognize and distinguish known and unknown information systematically before problem-solving begins. Second, justification, which refers to the ability to provide logical and mathematical reasoning for the selection of formulas, concepts, or solution steps used. Third, inference, which refers to the ability to draw valid conclusions from identified and analyzed data and concepts, including performing independent calculations and evaluating the results. Fourth, clarification, which refers to the ability to clarify and verify obtained information or results, including identifying underlying assumptions in mathematical models. Fifth, strategy formulation, which refers to the ability to systematically organize solution steps, select the most effective methods, and structure the problem-solving process independently from beginning to end. These five indicators were selected because they represent a systematic critical thinking process formed through adaptive interaction between students and artificial intelligence (Lawasi et al., 2024).

In this study, artificial intelligence specifically refers to ChatGPT as a representation of the most widely used conversational AI system among students. ChatGPT is capable of

responding to questions in natural language, providing structured mathematical explanations, and presenting step-by-step solutions. Alamsyah (2025) explains that in education, artificial intelligence is a computer system capable of simulating human logic through data analysis, pattern recognition, and automated decision-making, thereby offering more personalized and efficient learning experiences. Farizi et al. (2024) found that the structured use of ChatGPT can improve students' Higher Order Thinking Skills (HOTS), while Vebibina et al. (2025) showed that ChatGPT is effective in developing HOTS-based evaluation instruments. However, Agustina and Suharya (2024) emphasize that the integration of artificial intelligence must be accompanied by guidance that encourages active cognitive engagement rather than passive use focused solely on obtaining instant answers. Raitskaya and Tikhonova (2025) also warn that without such guidance, interaction with artificial intelligence may lead to cognitive dependency that weakens independent thinking.

The topic of trigonometric ratios in Phase E of the Merdeka Curriculum requires students to solve problems involving right triangles and their applications in real-life contexts (Kemendikbudristek, 2022). This ability includes identifying types of trigonometric ratios, selecting appropriate ratios based on available information, performing calculations, and interpreting results within problem contexts. The abstract nature of this material and its requirement for modeling real-life situations into mathematical representations make it highly suitable for examining critical thinking skills. Suendarti and Liberna (2021) found that high school students often fail to relate trigonometric ratio concepts to real-life contexts, indicating that their critical thinking processes have not yet developed optimally. The appropriate use of artificial intelligence has the potential to bridge this gap by providing adaptive visualizations, responsive conceptual explanations, and immediate feedback on students' solution steps. Relevant previous studies include those by Brazao and Tinoca (2025), Ratnawati et al. (2024), Ratnasari and Zikri Sholeha (2025), Shafira et al. (2025), and Fitri et al. (2025), all of which examine the relationship between artificial intelligence and critical thinking in mathematics learning, but none specifically analyze the synchronization between ChatGPT responses and vocational high school students' actual answers in trigonometric ratios.

The conceptual framework of this study illustrates a mediating causal relationship, where students' critical thinking skills are mediated by the interaction patterns they develop. Artificial intelligence encourages students to identify problems, analyze data, evaluate solutions, and draw logical conclusions when solving trigonometric ratio problems. However, this mediating process is only effective when students have an active and reflective learning orientation. The interaction shapes a structured critical thinking process through five stages: identification enables students to recognize the structure of problems, justification promotes conceptual understanding, inference produces valid conclusions, clarification ensures the accuracy of results, and strategy formulation represents the peak of cognitive synthesis. Thus, artificial intelligence functions most optimally when it acts as a catalyst that accelerates and enriches each of these stages, rather than as an agent that takes over the thinking process from students.

In addition to the five critical thinking indicators used as the main analytical framework, this study also considers the affective dimension of artificial intelligence use in learning. Shafira et al. (2025) found that students who use artificial intelligence as a learning resource show increased confidence in solving complex mathematical problems because they feel they have a partner available for consultation at any time. However, Ramadhan et al. (2025) warn that confidence built on dependence on artificial intelligence is pseudo and unsustainable, as students do not develop genuine internal competencies. This affective dimension must be considered in designing learning interventions, as enhancing students'

critical awareness of the limitations of artificial intelligence without undermining their motivation and confidence represents a subtle yet crucial pedagogical challenge in implementing artificial intelligence in mathematics classrooms.

The position of this study within the landscape of technology-based mathematics education literature can be identified through three main contributions. First, this study introduces the concept of synchronization as a more operational unit of analysis compared to merely measuring learning outcomes or perceptions of artificial intelligence. By directly analyzing the similarities and differences between ChatGPT responses and students' actual answers, this study provides more concrete empirical evidence of the cognitive processes that occur. Second, this study contributes to understanding the heterogeneity of artificial intelligence's impact on mathematics learning, as its effects are neither universal nor homogeneous but vary significantly depending on students' metacognitive capacities and learning orientations. Third, with the specific context of trigonometric ratios in vocational high schools, this study offers findings that can be directly applied in designing technology-based learning in Indonesian vocational education, which has received relatively limited attention in research on artificial intelligence integration in mathematics education.

METHODS

This study employs a qualitative approach using a descriptive method. This approach was chosen because it aligns with the research objective, which is to provide an in-depth description of the phenomenon of artificial intelligence use in relation to students' critical thinking skills on the topic of trigonometric ratios. By avoiding the manipulation of variables, the qualitative approach allows the researcher to gain a comprehensive understanding of students' interactions with technology in real-world contexts. The descriptive method is used to present the research findings systematically, factually, and accurately regarding the conditions observed in the field. Through this method, the researcher seeks to uncover the meaning behind the interaction processes between students and artificial intelligence technology during the learning activities.

The study was conducted at SMK Wikrama 1 Jepara, located at Jl. Kelet Ploso No. KM 36, Karang Anyar, Kelet, Keling District, Jepara Regency, Central Java 59454. The selection of this location was based on several considerations: the school has systematically implemented digital learning technologies, tenth-grade students are studying trigonometric ratios in line with the research focus, mathematics teachers are open to technology-based innovations, and adequate internet facilities are available to support the use of online artificial intelligence platforms. The research subjects consisted of 22 students from class X RPL 1, selected purposively and divided into five heterogeneous groups, each consisting of four to five students. Each group was given two contextual essay problems: the first involved calculating the height of a flagpole using an angle of elevation and horizontal distance, and the second involved determining an angle of inclination or distance based on geometric information in a real-life measurement context.

Data were collected through three complementary techniques. First, a written test consisting of two contextual essay questions was administered to measure the five indicators of critical thinking. Each question was designed with structured sub-questions, each targeting a specific indicator. The test instrument was validated by two validators: a lecturer in Mathematics Education from Universitas Islam Sultan Agung and a mathematics teacher at SMK Wikrama 1 Jepara, considering language appropriateness, content relevance, and clarity of instructions. Second, structured interviews were conducted with representatives from each group using a validated interview guide, aiming to explore students' thinking processes and

their experiences in using artificial intelligence during problem-solving. Third, documentation of students' conversations with artificial intelligence was analyzed in detail to trace interaction patterns, types of questions posed, and how students responded to the information provided by artificial intelligence. Triangulation of these three data sources was used to ensure the validity and consistency of the findings.

Data analysis was carried out using the interactive analysis model proposed by Miles and Huberman, which consists of four concurrent components: data collection, data reduction, data display, and conclusion drawing. Data reduction involved coding ChatGPT conversations and students' answer sheets based on each critical thinking indicator, followed by identifying elements in the students' actual answers that originated from ChatGPT responses and those that reflected students' independent contributions. Synchronization analysis was conducted by systematically comparing the types of questions posed to ChatGPT, the quality of the responses obtained, and how students integrated or modified these responses in their actual answers. The classification of critical thinking skills into three categories (high, moderate, and low) was based on the degree of originality, elaboration, and cognitive transformation observed in the synchronization between ChatGPT conversations and students' actual answers.

The test instrument consisted of two contextual essay questions designed to measure the five indicators of critical thinking simultaneously within a series of structured sub-questions. The first problem presented a contextual situation involving the measurement of a flagpole's height using an angle of elevation and horizontal distance, with sub-questions sequentially addressing identification of information and angle position in a right triangle, justification for selecting appropriate trigonometric ratios, inference through height calculation, clarification of assumptions required for valid results, and strategy formulation for systematic problem-solving. The second problem presented a scenario involving measuring the width of a river using two different observation points with varying angles and distances, requiring more complex modeling skills. These two problems were selected due to their real-life relevance and their potential to elicit observable critical thinking processes that can be analyzed through interactions with artificial intelligence.

The research procedure was carried out in three main stages. The preparation stage included instrument validation, introduction of ChatGPT usage procedures to students, and preparation of structured answer sheets based on the five critical thinking indicators. The implementation stage took place over two learning sessions, during which each group worked on the two problems using ChatGPT as a supporting tool, documented all interactions with ChatGPT, and wrote their actual answers on the provided answer sheets. The data collection stage included in-depth interviews with one representative from each group conducted after all tasks were completed, aiming to confirm and deepen the findings from the analysis of answer sheets and ChatGPT conversations. All ChatGPT conversation data were transcribed verbatim into analysis documents to enable direct comparison between the content of the conversations and the students' actual answers for each critical thinking indicator.

RESULT

This study was conducted over two weeks involving 22 students from class X RPL 1 at SMK Wikrama 1 Jepara, organized into five groups. Data collection produced 22 written test answer sheets, 5 in-depth interview transcripts, and more than 50 ChatGPT conversation documentations covering all five critical thinking indicators across two different problems. Based on a comprehensive analysis of these three types of data, students' critical thinking abilities were classified into three categories as presented in Table 1.

Table 1. Recapitulation of students' critical thinking abilities based on artificial intelligence usage patterns

Group	Category	Description of Artificial Intelligence Usage Pattern
Group 1	Low (HTR)	Asking direct questions for final answers; copying entire ChatGPT responses; no independent verification; all five critical thinking indicators do not appear authentically in the answers
Groups 2, 3, 5	Moderate (HTS)	Using ChatGPT as an additional information source and validation tool; identification and justification indicators begin to appear; clarification and inference still depend on ChatGPT confirmation; strategies are partially adopted from ChatGPT
Group 4	High (HTT)	Using ChatGPT as an exploratory dialogic partner; independently developing and correcting responses; measurable differences between student answers and ChatGPT responses indicate authentic critical thinking across all indicators

Group 4, categorized as high ability, demonstrated the most productive pattern of artificial intelligence usage. In the identification indicator, students explicitly mapped the position of angles and sides in a right triangle before interacting with ChatGPT, using ChatGPT only to reinforce their initial understanding. In the justification indicator, students asked exploratory questions about why tangent was chosen instead of sine or cosine, then added independent elaboration regarding the unavailability of the hypotenuse, which did not appear in the ChatGPT response. In the inference indicator, the difference in the value of $\tan 34$ degrees used (0.674 by students vs. 0.6745 by ChatGPT) indicates independent calculation. In the clarification indicator, students proactively questioned the validity of model assumptions and integrated corrections for the observer's eye height into the final formula. In the strategy determination indicator, students added visualization steps of the triangle, unit identification, and final corrections that were not requested in the ChatGPT conversation.

Interview data provided additional information that enriched the understanding of differences among groups. A representative from Group 4 stated that before using ChatGPT, they had tried to understand the problem independently for several minutes and only used ChatGPT after feeling the need for confirmation or deeper conceptual explanation. A representative from Group 2 stated that they used ChatGPT to check the steps they had already planned, indicating that ChatGPT was positioned as an external validator. A representative from Group 1 revealed that they directly used ChatGPT because they did not know where to start. These differences in the starting point of interaction with ChatGPT, ranging from prior independent understanding to total confusion, explain why the resulting synchronization patterns differ fundamentally among the three ability categories and confirm that patterns of interaction with ChatGPT reflect students' pre-existing learning orientations.

Groups 2, 3, and 5, categorized as moderate ability, showed varying patterns but were generally characterized by using ChatGPT as an additional information source with limited selection and adaptation ability. Group 2 demonstrated fairly good independent identification before using ChatGPT, was able to adapt ChatGPT's justification explanations into their own words, and compared the results of independent calculations with ChatGPT responses. Group 3 showed adequate identification but justification that relied more on ChatGPT, with questions that were confirmatory in nature. Group 5 showed a pattern closest to the boundary between moderate and low categories, where the processes of justification and strategy determination were almost entirely dependent on ChatGPT guidance, although there were still follow-up questions indicating minimal clarification efforts.

Group 1, categorized as low ability, showed a very different pattern. Analysis of ChatGPT conversations revealed that students submitted the entire problem text as a single

question without any prior independent identification process. The comprehensive ChatGPT response was then almost entirely copied onto the answer sheet with slight formatting modifications. Although the answer sheets appeared complete with all required components, synchronization analysis showed that the content of each section was a replica of the ChatGPT response. No element in the actual answers of Group 1 differed substantively from the ChatGPT responses obtained, indicating that no meaningful cognitive transformation occurred throughout the problem-solving process.

Another important aspect identified in the analysis results is the pattern of questions posed by students to ChatGPT. Group 4 consistently asked exploratory and multi-layered questions: beginning with conceptual questions about why a particular approach could be used, followed by questions about procedural steps, and ending with critical questions about the validity of the underlying model assumptions. This layered questioning pattern reflects high metacognitive ability, as students are aware of what they do not know and design their interaction with ChatGPT to systematically fill those gaps in understanding. In contrast, Group 1 asked only a single comprehensive question that covered the entire problem at once, without a staged structure, resulting in a very comprehensive ChatGPT response but not encouraging active thinking processes from students. This finding regarding questioning patterns serves as an additional indicator distinguishing the three categories of critical thinking ability.

In-depth interviews with representatives from each group provided confirmation and additional nuance to the synchronization analysis findings. A representative from Group 4 stated that they consciously used ChatGPT not to obtain answers, but to ensure that their line of thinking was correct before performing their own calculations. This statement indicates strong metacognitive awareness regarding the role of ChatGPT as a verification tool rather than a primary source of answers. A representative from Group 2 stated that they used ChatGPT mainly to check whether the steps they had planned were correct, reflecting a confirmatory orientation typical of the moderate category. A representative from Group 1 honestly admitted that they copied answers from ChatGPT because they felt unable to solve the problem independently, a statement that confirms the replica synchronization pattern identified. These interview findings strengthen the validity of the three-category classification derived from synchronization analysis and demonstrate that data triangulation successfully produced a consistent and cohesive depiction of students' critical thinking patterns in interacting with artificial intelligence.

DISCUSSION

This discussion presents an in-depth analysis of the synchronization between students' actual answers in their answer sheets and ChatGPT responses for each critical thinking indicator. The synchronization analysis was conducted comparatively across the three ability categories to identify how the quality of interaction with artificial intelligence is reflected in the quality of students' written responses. The empirical findings are then linked to theories and previous studies to produce a comprehensive interpretation and contribute to the development of knowledge regarding artificial intelligence literacy in mathematics learning.

1. Synchronization of Low-Ability Students' Answers (Group 1)

Figure 1 presents the answer sheet of Group 1 for problem number 1. The contextual problem requires students to calculate the height of a flagpole given an elevation angle of 34° and a horizontal distance of 52 meters. Although the answer sheet appears complete with all

required components, in-depth analysis reveals that the content of each component is a replica of the ChatGPT response.

Lembar Jawaban

1. a. Informasi diketahui dan yang dicari

Diketahui :

- Sudut elevasi = 39°
- Jarak horizontal ketiang = 52 m
- Tanah datar

Di tanya :

- Tinggi tiang bendera

Posisi segitiga siku-siku :

- Sudut 39° berada diposisi mata dike.
- Sisi samping (alas) = 52 m (jarak horizontal).
- Sisi depan = selisih tinggi ujung tiang terhadap tinggi mata Dika.
- Sisi miring = garis pandang ke ujung tiang.

b. Alasan memilih perbandingan trigonometri

Yang diketahui sudut dan sisi samping, yang dicari sisi depan $\rightarrow$ gunakan tangen :

$$\tan B = \frac{\text{sisi depan}}{\text{sisi samping}}$$

c. Perhitungan sisi depan

$$\text{sisi depan} = 52 \times \tan 39^\circ$$

$$\tan 39^\circ = 0,6745$$

$$\text{sisi depan} = 52 \times 0,6745 = 35,1 \text{ m}$$

Jadi selisih tinggi dari mata Dika ke puncak tiang = 35,1 m

d. Apakah itu tinggi tiang sebenarnya ?

Belum tentu benar.

Perlu mempertimbangkan :

- Tinggi mata Dika dari tanah
- Posisi pengukuran harus sejajar dengan kaki tiang.
- Tanah harus datar.

Tinggi tiang sebenarnya = hasil perhitungan + tinggi mata Dika.

Indicators:

- Identifikasi
- Justifikasi
- Inferensi
- klarifikasi
- Penentuan Strategi

2. Langkah sistematis **Lembar Jawaban** menentukan tinggi tiang

1. Ukur jarak horizontal ketiang (52 m).
2. Ukur sudut elevasi ke puncak (39°)
3. Hitung selisih tinggi dengan rumus tangen.
4. Tambahkan tinggi mata pengamat dari tanah.
5. Peroleh tinggi tiang sebenarnya.

Picture 1. Answer Sheet of Group 1 (Low Ability)

In the identification indicator, students wrote down the known and asked information completely on the answer sheet. Figure 2 shows the conversation between Group 1 and ChatGPT for the identification indicator. Analysis of the conversation reveals that this information was obtained by copying the entire problem text into ChatGPT, which then automatically responded by mapping the information in a structured manner. The students did not perform independent identification before interacting with ChatGPT.

Dika ingin mengetahui tinggi sebuah tiang bendera di halaman sekolah. Ia berdiri di suatu titik di tanah yang datar dan mengamati ujung tiang bendera menggunakan alat busur derajat. Sudut elevasi antara garis pandang dari kepala Dika ke ujung tiang bendera adalah 34° . Jarak horizontal antara posisi Dika dan tiang bendera adalah 52 meter. a. Sebutkan informasi yang diketahui dan tentukan besaran yang ingin dicari. Jelaskan juga posisi sudut serta sisi-sisi segitiga siku-siku yang terbentuk.

a. Informasi yang diketahui:

- Sudut elevasi (sudut antara garis pandang Dika ke puncak tiang dan garis horizontal) = 34°
- Jarak horizontal antara Dika dan tiang bendera = 52 meter
- Tanah datar (membentuk segitiga siku-siku)

Besaran yang ingin dicari:

- Tinggi tiang bendera (panjang sisi tegak segitiga)

Posisi sudut dan sisi segitiga siku-siku:

Jika kita gambarkan situasinya sebagai segitiga siku-siku:

- Titik pertama: posisi mata/kepala Dika
- Titik kedua: kaki tiang bendera di tanah
- Titik ketiga: ujung (puncak) tiang bendera

Maka:

- Sudut 34° berada di posisi Dika (antara garis horizontal tanah dan garis pandang ke puncak tiang).
- Sisi-sisi segitiga:
 - Sisi samping (adjacent) terhadap sudut 34° = jarak horizontal Dika ke tiang = 52 m
 - Sisi depan (opposite) terhadap sudut 34° = tinggi tiang bendera (yang dicari)
 - Sisi miring (hipotenusa) = garis pandang dari kepala Dika ke puncak tiang

Jadi, tinggi tiang merupakan sisi depan terhadap sudut elevasi 34° dalam segitiga siku-siku tersebut.

Picture 2. ChatGPT Conversation of Group 1 – Identification Indicator

The fundamental mismatch between the completeness of identification in the answer sheet and the absence of an independent identification process serves as the first indicator that critical thinking skills are not genuinely fulfilled. In the justification indicator, the answer sheet states the reason for using tangent because the adjacent side is known and the opposite side is sought. Although substantively correct, this explanation is entirely derived from the ChatGPT response without independent elaboration. In the inference indicator, the calculations written are identical to the steps provided by ChatGPT, including the value of $\tan 34^\circ = 0.6745$ and the result of 35.07 meters, with no evidence of independent computation. In the clarification indicator, the explanation regarding the model assumptions is also a copy of the ChatGPT explanation. Similarly, in the strategy determination indicator, the systematic steps in the answer sheet replicate the structure of the ChatGPT response. This phenomenon confirms the concern raised by Firdaus and Firman (2023) that inappropriate use of artificial intelligence creates an illusion of understanding, where students believe they understand but are merely repeating information without genuine conceptual internalization.

2. Synchronization of Moderate-Ability Students' Answers (Group 2)

Figure 3 presents the answer sheet of Group 2, which shows significant differences compared to Group 1 in how students formulate their answers in relation to ChatGPT responses.

Lembar Jawaban

1.

a.) diketahui:

- sudut evaluasi ke puncak tiang = 34°
- jarak horizontal dika ke tiang = 52 meter
- tanah datar

ditanyakan:

- tinggi tiang bendera

Segitiga yang terbentuk terbentuk segitiga siku-siku dengan:

- sudut diposisi dika = 34°
- sisi alas (sisi samping terhadap sudut 34°) = 52 m
- sisi tegak (sisi depan terhadap sudut 34°) = tinggi tiang
- sudut di kaki tiang = 90°

b.) karena diketahui:

- sudut (34°)
- sisi samping (52 m)

dan yang dicari adalah sisi depan, maka perbandingan yang tepat adalah tangen ($\tan$) karena:

$$\tan \theta = \frac{\text{sisi depan}}{\text{sisi samping}}$$

c.) $\tan 34^\circ = \frac{\text{tinggi}}{52}$

$$\text{tinggi} = 52 \times \tan 34^\circ$$

nilai

$$\tan 34^\circ = 0,6745$$

$$\text{tinggi} = 52 \times 0,6745$$

$$\text{tinggi} \approx 35,07 \text{ meter}$$

Jadi tinggi tiang = 35,1 meter

d.) belum tentu sepenuhnya tepat. karena sudut evaluasi dibuat dari tinggi mata dika, bukan dari permukaan tanah artinya:

tinggi sebenarnya = hasil perhitungan + tinggi mata dika

misalnya jika tinggi mata dika 1,5m

$$35,07 + 1,5 = 36,57 \text{ meter}$$

e.)

1. gambarkan segitiga siku-siku dari situasi
2. tentukan sisi depan dan sisi samping terhadap sudut
3. gunakan rumus: $\tan \theta = \frac{\text{sisi depan}}{\text{sisi samping}}$
4. periksa kembali satuan dan pembuatan

Identifikasi

Justifikasi

Inferensi

Klarifikasi

Penentuan Strategi

Picture 3. Answer Sheet of Group 2 (Moderate Ability)

In the identification indicator, Group 2 first wrote down the identification based on their own understanding before using ChatGPT as confirmation. The questions posed to ChatGPT were confirmatory in nature: asking ChatGPT to explain the position of the angle and the sides of the formed triangle to verify their initial understanding. There is a positive synchronization indicating that the students' independent identification aligns with ChatGPT's response, showing that ChatGPT was used to reinforce initial understanding rather than replace it. In the justification indicator, Group 2 independently stated that tangent is used because the angle and the adjacent side are known, and the opposite side is sought, using the formula $\tan \theta = \frac{\text{opposite side}}{\text{adjacent side}}$. The students' answer represents a summary of the more detailed ChatGPT response, demonstrating conceptual internalization rather than word-for-

word copying. In the inference indicator, students performed calculations independently, with results consistent with ChatGPT, supported by limited verification through result comparison. In the clarification indicator, Group 2 stated that the result may not be entirely accurate because the angle of elevation is measured from Dika's eye level, reflecting a critical acknowledgment that they did not passively accept ChatGPT's output. However, this clarification remains limited to recognizing the issue without deeper correction. In the strategy determination indicator, students wrote structured steps that were partially internalized from their interaction with ChatGPT. These findings support the statement of Agustinasari and Fiqry (2025) that artificial intelligence can promote logical thinking through result analysis, although its effectiveness remains limited at the level of adaptation and has not yet reached transformation

3. Synchronization of High-Ability Students' Answers (Group 4)

Figures 4 and 5 present the answer sheets of Group 4 for problem number 1, showing the highest-quality synchronization pattern. In each indicator, there are elements in the answer sheets that do not originate from ChatGPT responses, but rather represent students' original contributions based on their own conceptual understanding.

The image shows a handwritten student answer sheet titled "Lembar Jawaban". It contains two parts, A and B, which are analyzed for synchronization with ChatGPT responses.

Part A: Jawaban A: yang diketahui

- > sudut elevasi 34°
- > jarak horizontal dika ketiang bendera = 52 m
- > tanah datar (membentuk siku)
- > garis pandang dri kpnla dika keujung tiang bendera yg dicari =
- > tinggi tiang bendera

Posisi sudut dan sisi Pd yg terbentuk:

- terbentuk segitiga siku dg:
- > sudut 34° berada di posisi dika (antara tanah & garis pandang)
- > sudut samping (lain) = Jarak horizontal = 52 m
- > sisi depan (tegak) = tinggi tiang bendera (yg dicari)
- > sisi miring = garis pandang dr kpnla dika keujung tiang bendera yg diketahui adalah:
- > sudut diketahui $\Rightarrow 34^\circ$
- > sisi samping diketahui $\Rightarrow 52$ m
- > sisi depan (tinggi tiang) $\Rightarrow$ yg ingin dicari

Part B: Jawaban B:

Perbandingan trigonometri yg paling tepat adalah tangen (tan).

Pada yg terbentuk

- > sudut yg diket: 34° (sudut elevasi di posisi dika)
- > sisi yg diket: Jarak horizontal 52 m $\Rightarrow$ sisi samping (adjacent)
- > yg dicari tinggi tiang $\Rightarrow$ sisi depan (opposite)

Rumus tangen $\tan \theta = \frac{\text{sisi depan}}{\text{sisi samping}}$

Alasan:

- > tdk mengetahui sisi miring, tdk cocok memakai sinus / cosinus
- > Mengetahui sudut & sisi samping
- > yg langsung dihubungkan sisi depan & sisi samping tangen

Two arrows point from the handwritten text to boxes labeled "Identifikasi" and "Justifikasi".

Picture 4. Answer Sheet of Group 4 for Problem 1 (Part 1) – Identification and Justification

Lembar Jawaban

Jawaban c.

Rumus: $\tan \theta = \frac{\text{sisidepan}}{\text{sisisamping}}$

- > sudut $\theta = 34^\circ$
- > sisi samping = 52 m
- > sisi depan = tinggi tiang (L)
- $\tan 34^\circ = \frac{L}{52}$
- $L = 52 \times \tan 34^\circ$

Jadi nilainya:

$\tan 34^\circ \approx 0.674$

$L = 52 \times 0.674 \approx 35.05$

panjang sisidpan ≈ 35 m

Jawaban d.

hasil (L) menjadi tinggi sebenarnya:

- > tinggi mata dik. sejajar dg permukaan tanah (L_m)
- > sudut elevasi diukur benar dg garis horizontal
- > tanah benar: datar
- > pengukuran jarak 52 m
- > alat ukur tdk meleset
- faktor 4 diperhatikan
- > tinggi mata dik. dari tanah $\Rightarrow$ sekitar 1,4-1,6 m
- > ketelitian sudut 34° (Perkiraan bisa meleset)
- > ketelitian $\neq$ jarak horizontal 52 m
- > posisi harus sejajar dg mata tinggi

Jawaban e

identifikasi data

- > Evaluasi: 34° jarak horizontal ketinggi 52
- > tanah datar

sketsa 

tinggi sebagai ujung alas, ujung tiang sebagai puncak, tanah sudut 34° di posisi 34° , alas = 52 m, tinggi tiang = sisidpan

Perbandingan trigonometri yg sesuai: $\tan = \frac{\text{sisidpan}}{\text{sisisamping}}$

$\tan 34^\circ = \frac{\text{tinggi}}{52}$

hitung tinggi dari garis Pandang

tinggi: $52 \times \tan 34^\circ \approx 35$ m

Koreksi dg tinggi mata Pengamat

tinggi mata dik. dr tanah (misal 1,5 m)

- > asumsi pengukuran tanah benar: datar
- > sudut diukur dg garis horizontal
- > jarak diukur benar
- > alat ukur cukup teliti

Inferensi

Klarifikasi

Penentuan Strategi

Picture 5. Answer Sheet of Group 4 for Problem 1 (Part 2) – Inference, Clarification, and Strategy Determination

In the identification indicator, Group 4's answer sheet is highly structured and detailed. Students not only recorded the known and asked information but also explicitly mapped the position of angles and sides in the right triangle. The 34° angle is located at Dika's eye level, the adjacent side is 52 meters, and the opposite side represents the height of the flagpole being sought. Figure 6 presents the identification conversation, which is exploratory in nature;

the questions posed ask ChatGPT to explain the entire structure of the problem in a sequential and conceptual manner before the calculation process begins.

Saya sedang mempelajari penerapan perbandingan trigonometri pada segitiga siku-siku. Ada sebuah situasi di mana Dika ingin mengetahui tinggi tiang bendera di halaman sekolah, ia berdiri di tanah yang datar pada jarak 52 meter dari tiang bendera. Dengan menggunakan busur derajat, ia mengukur sudut elevasi dan garis pandang matanya ke ujung tiang bendera sebesar 34° .

Tolong bantu saya memahami permasalahan ini secara runtut. Jelaskan terlebih dahulu informasi apa saja yang diketahui dari situasi tersebut dan besaran apa yang sebenarnya ingin dicari. Uraikan juga bagaimana posisi sudut serta sisi-sisi segitiga yang terbentuk jika digambarkan dalam model matematika.

Mari kita pahami situasi ini secara runtut dan konseptual sebelum menghitung.

✦ Informasi yang diketahui

Dari cerita, kita punya data berikut:

- Jarak Dika ke tiang bendera = 52 meter
- Sudut elevasi ke puncak tiang = 34°
- Posisi berdiri di tanah datar
- Garis pandang mata menuju ujung tiang

🎯 Besaran yang ingin dicari

Yang ingin diketahui adalah:

- ✓ tinggi tiang bendera

Artinya kita ingin mencari panjang vertikal dari:

- kaki tiang → puncak tiang.

Situasi ini membentuk **segitiga siku-siku**. Mari kita identifikasi titik-titiknya.

Titik-titik penting

- Titik A = posisi mata Dika di tanah
- Titik B = kaki tiang bendera
- Titik C = puncak tiang

📐 Posisi sudut dalam segitiga

Sudut elevasi 34° berada di:

- 👉 sudut antara tanah datar dan garis pandang Dika ke puncak.

Jadi:

- Sudut di titik A = 34°
- Sudut siku-siku berada di kaki tiang (B)

🔍 Identifikasi sisi-sisi segitiga

Jika digambarkan:

1. Sisi samping (adjacent)

Ini adalah jarak mendatar dari Dika ke tiang:

$$AB = 52 \text{ m}$$

- 👉 sisi yang diketahui

2. Sisi depan (opposite)

Ini adalah tinggi tiang bendera:

$$BC = \text{tinggi tiang}$$

- 👉 sisi yang ditanya

3. Sisi miring (hipotenusa)

Ini adalah garis pandang mata Dika ke puncak tiang:

$$AC = \text{garis pandang}$$

- 👉 tidak diketahui dan tidak perlu langsung

Picture 6. ChatGPT Conversation of Group 4 – Identification Indicator

The synchronization in the identification indicator demonstrates a constructive dialogic pattern. ChatGPT provides a conceptual framework in the form of a right triangle model with the identification of points A, B, and C, along with explanations of its sides. The students then integrate this into their answer sheet using slightly different wording, including the addition of explanations regarding the position of the angle that are not explicitly stated in the ChatGPT response. This addition indicates the occurrence of an active cognitive process in which students process information from ChatGPT and synthesize it with their own understanding. This finding is consistent with the perspective of Samaray (2025), which states that effective artificial intelligence acts as an intellectual collaborator that helps students construct logical reasoning independently.

In the justification indicator, Figure 7 presents a conversation in which Group 4 poses in-depth questions about why trigonometric ratio concepts can be applied and the rationale behind selecting a ratio that determines the side opposite the angle of elevation. ChatGPT's response provides two mathematical justifications: the formation of a right triangle from a real-world situation and the availability of an angle along with one known side.

Kedua, jelaskan mengapa konsep perbandingan trigonometri dapat digunakan dalam kasus ini dan apa alasan pemilihan perbandingan yang tepat untuk menentukan sisi yang berhadapan dengan sudut elevasi

Baik — kita bahas alasan matematisnya secara runtut dan logis.

🌸 Mengapa perbandingan trigonometri bisa digunakan?

Konsep trigonometri dapat digunakan karena situasi ini memenuhi syarat utama penerapan trigonometri, yaitu:

✅ 1. Terbentuk segitiga siku-siku

Dari situasi:

- tanah datar → garis horizontal
- tiang bendera → garis vertikal
- garis pandang → garis miring

Ketiganya saling tegak lurus sehingga membentuk segitiga siku-siku.

👉 Trigonometri pada dasarnya memang didefinisikan untuk segitiga siku-siku.

✅ 2. Ada sudut yang diketahui

Dika mengukur sudut elevasi 34° .

Dalam trigonometri, jika:

- satu sudut diketahui, dan
- minimal satu sisi diketahui

maka sisi lain bisa ditentukan melalui perbandingan trigonometri.

👉 Syarat ini terpenuhi.

✓ 3. Ada sisi yang diketahui

Yang sudah diketahui adalah:

- jarak mendatar = 52 m (sisi samping terhadap sudut)

Dengan kombinasi:

- sudut diketahui
- satu sisi diketahui

→ trigonometri bisa digunakan untuk mencari sisi lain.

🔗 Mengapa memilih perbandingan yang melibatkan sisi depan?

Tujuan soal adalah mencari **tinggi tiang**, yaitu sisi yang berhadapan dengan sudut elevasi.

Sekarang kita analisis posisi sisi terhadap sudut 34° .

📐 Posisi relatif terhadap sudut 34°

Terhadap sudut elevasi:

- sisi depan (opposite) → tinggi tiang ? (ditanya)
- sisi samping (adjacent) → 52 m ✓ (diketahui)
- sisi miring (hipotenusa) → garis pandang (tidak diketahui)

🔍 Memilih rasio yang tepat

Kita pilih rasio yang:

- melibatkan sisi yang dicari, dan
- melibatkan sisi yang diketahui.

Mari cek tiga rasio utama.

✗ Sinus

$$\sin \theta = \frac{\text{depan}}{\text{miring}}$$

Masalah: sisi miring **tidak diketahui**.

→ kurang praktis.

✗ Cosinus

$$\cos \theta = \frac{\text{samping}}{\text{miring}}$$

Masalah: tetap butuh sisi miring.

→ tidak langsung dapat tinggi.

✓ Tangen (pilihan tepat)

$$\tan \theta = \frac{\text{depan}}{\text{samping}}$$

Keunggulan:

- sisi depan = yang dicari ✓
- sisi samping = yang diketahui ✓
- tidak perlu sisi miring ✓

👉 Ini rasio paling efisien.

Picture 7. ChatGPT Conversation of Group 4 – Justification Indicator

The answer sheet of Group 4 in the justification section does not merely copy the two reasons provided by ChatGPT. The students add a crucial independent elaboration: the reason that tangent is chosen because the hypotenuse is unknown, thus sine and cosine cannot be used. This addition regarding the unavailability of the hypotenuse does not appear in the ChatGPT response, demonstrating that students are able to develop justification independently based on their conceptual understanding of the definitions of the three trigonometric functions. This represents a high-level synchronization in which ChatGPT functions as a trigger for exploration rather than a single source of answers.

In the inference indicator, Figure 8 presents a conversation in which Group 4 asks ChatGPT to demonstrate the calculation steps in a sequential manner. ChatGPT responds with five systematic steps, including data identification, selection of the tangent ratio, value substitution, calculation of the tangent value (0.6745), and the calculation of the final height (35.07 meters).

Ketiga, tunjukkan bagaimana menggunakan perbandingan trigonometri yang sesuai untuk menentukan panjang sisi depan segitiga berdasarkan data yang diketahui.

Baik — kita selesaikan langkah perhitungan secara runtut untuk menentukan panjang sisi depan (tinggi tiang).

Iya

Mantap — kita hitung secara runtut dan jelas 🍌

🌟 **Data yang diketahui**

- Jarak mendatar ke tiang (sisi samping) = 52 m
- Sudut elevasi = 34°
- Yang dicari = tinggi tiang (sisi depan)

▲ **Langkah 1: Pilih perbandingan yang tepat**

Karena yang diketahui:

- sisi samping ✓
- sudut ✓
- sisi depan yang dicari ✓

Maka gunakan **tangen**:

$$\tan(\theta) = \frac{\text{sisi depan}}{\text{sisi samping}}$$

🧮 **Langkah 2: Substitusi nilai**

Misalkan tinggi tiang = h

$$\tan(34^\circ) = \frac{h}{52}$$

🔍 **Langkah 3: Ubah rumus untuk mencari h**

$$h = 52 \times \tan(34^\circ)$$

📊 **Langkah 4: Hitung nilai tangen**

$$\tan(34^\circ) \approx 0,6745$$

🖋️ **Langkah 5: Hitung tinggi**

$$h = 52 \times 0,6745$$

$$h \approx 35,07 \text{ meter}$$

Picture 8. ChatGPT Conversation of Group 4 – Inference Indicator

The critical difference that demonstrates the authenticity of Group 4's inference lies in the value of $\tan 34^\circ$. ChatGPT uses 0.6745 (with four decimal places), whereas the students use 0.674 (with three decimal places), resulting in heights of 35.05 meters and 35.07 meters, respectively. This difference is not an error but rather clear evidence that the students performed independent calculations with their own rounding decisions. Students who merely copy would certainly use values and results identical to those provided by ChatGPT. This measurable difference constitutes the strongest evidence that the inference indicator is authentically fulfilled, consistent with the findings of Ramadhan et al. (2025), which state that students who regularly evaluate artificial intelligence outputs develop stronger reflective thinking.

In the clarification indicator, Figure 9 presents a conversation in which Group 4 proactively questions whether the calculated result can be directly considered as the actual height of the flagpole. This question does not arise from the demands of the problem but from the students' critical initiative, demonstrating their awareness that mathematical models are always based on assumptions that need to be verified.

Keempat, berikan analisis apakah hasil perhitungan tersebut langsung dapat dianggap sebagai tinggi tang bendera yang sebenarnya, serta jelaskan asumsi atau faktor apa saja yang perlu diperhatikan agar kesimpulan tersebut benar.

Pertanyaan ini sangat penting 🧡 — karena dalam pengukuran nyata, hasil hitungan belum tentu langsung sama dengan tinggi sebenarnya tanpa mempertimbangkan beberapa asumsi.

Mari kita analisis secara logis.

🌀 Apakah hasil perhitungan langsung merupakan tinggi sebenarnya?

Jawaban singkat:

👉 Bisa mendekati tinggi sebenarnya, tetapi hanya jika beberapa asumsi terpenuhi.

Jika asumsi tidak terpenuhi, hasil bisa:

- sedikit meleset, atau
- bahkan cukup jauh.

✅ Asumsi penting yang harus terpenuhi

1. Tinggi mata Dika diabaikan atau diperhitungkan

Dalam model matematika, kita menganggap sudut elevasi diukur dari permukaan tanah.

Padahal kenyataannya:

- sudut diukur dari mata Dika ($\pm 1,4$ – $1,6$ m dari tanah).

🔴 Jika tinggi mata tidak diperhitungkan:

- hasil 35 m adalah tinggi dari mata ke puncak,
- bukan tinggi tiang sebenarnya.

✅ Agar akurat:

$$\text{tinggi tiang sebenarnya} = \text{hasil hitung} + \text{tinggi mata}$$

2. Tanah benar-benar datar

Perhitungan mengasumsikan:

- posisi Dika dan kaki tiang sejajar horizontal.

Jika kenyataannya:

- tanah menanjak, atau
- menurun,

maka sudut elevasi tidak merepresentasikan segitiga siku-siku sempurna.

👉 Ini bisa menyebabkan error.

3. Tiang benar-benar tegak lurus

Model menganggap tiang:

- berdiri vertikal sempurna.

Jika tiang:

- miring sedikit saja,

maka:

- sisi depan segitiga bukan tinggi vertikal sebenarnya.

4. Pengukuran sudut akurat

Busur derajat manual bisa menimbulkan error karena:

- salah membaca skala,
- tangan tidak stabil,
- garis pandang tidak tepat ke puncak.

⚠️ Perubahan 1–2° saja bisa mengubah hasil cukup besar.

5. Jarak 52 m diukur tepat

Kesalahan jarak juga berpengaruh langsung karena:

$$h = (\text{jarak}) \times \tan(\theta)$$

Jika jarak meleset → tinggi ikut meleset.

Picture 9. ChatGPT Conversation of Group 4 – Clarification Indicator

ChatGPT responds by analyzing five critical assumptions. Group 4's answer sheet does not copy the entire list of these assumptions. Instead, the students perform a critical selection by choosing the most relevant assumption (Dika's eye height) and actively integrating it into the correction formula: Actual height of the flagpole = calculated result + Dika's eye height. This transformative synchronization demonstrates that students do not merely receive information from ChatGPT but process it through evaluation and selection that reflect higher-order critical thinking skills. Raitskaya and Tikhonova (2025) emphasize that productive interaction with artificial intelligence strengthens cognitive analytical abilities, provided that users actively manage their own cognitive processes.

In the strategy determination indicator, Figure 10 presents a conversation in which Group 4 asks ChatGPT to explain systematic steps for accurately determining the height of the flagpole. ChatGPT responds with four main steps.

Kelima, jelaskan langkah-langkah sistematis yang harus dilakukan secara runtut untuk menentukan tinggi tiang bendera secara tepat berdasarkan situasi yang diberikan

Berikut langkah-langkah sistematis dan runtut untuk menentukan tinggi tiang bendera secara tepat dari situasi yang diberikan.

Langkah 1: Memahami situasi dan mengidentifikasi data

Pertama, baca soal dan tentukan:

Diketahui:

- jarak mendatar ke tiang (52 m)
- sudut elevasi (34°)
- posisi di tanah datar

Ditanya:

- tinggi tiang bendera

👉 Tahap ini penting agar tidak salah memilih rumus.

▲ Langkah 2: Membuat model segitiga siku-siku

Gambarkan situasi menjadi segitiga:

- garis tanah → horizontal
- tiang → vertikal
- garis pandang → miring

Pastikan:

- sudut elevasi berada di posisi pengamat,
- sudut siku-siku di kaki tiang.

👉 Ini memastikan trigonometri bisa digunakan.

Langkah 3: Menentukan posisi sisi terhadap sudut

Relatif terhadap sudut elevasi:

- sisi samping (adjacent) = jarak mendatar = 52 m
- sisi depan (opposite) = tinggi tiang (yang dicari)
- sisi miring = garis pandang

👉 Identifikasi ini menentukan pilihan rasio.

Langkah 4: Memilih perbandingan trigonometri yang tepat

Karena diketahui:

- sisi samping ✓
- sudut ✓
- sisi depan dicari ✓

Gunakan:

$$\tan \theta = \frac{\text{sisi depan}}{\text{sisi samping}}$$

👉 Tangen paling langsung untuk kasus ini.

Langkah 5: Menyusun persamaan

Substitusikan data:

$$\tan(34^\circ) = \frac{h}{52}$$

dengan h = tinggi tiang dari mata pengamat.

 Langkah 6: Menghitung nilai tinggi

Ubah rumus:

$$h = 52 \times \tan(34^\circ)$$

Hitung dengan kalkulator untuk memperoleh tinggi.

 Langkah 7 (PENTING): Koreksi tinggi mata pengamat

Untuk hasil lebih tepat, tambahkan tinggi mata Dika:

$$\text{tinggi tiang sebenarnya} = h + \text{tinggi mata}$$

Langkah ini sering dilewati di soal sederhana tetapi penting di pengukuran nyata.

 Langkah 8: Menarik kesimpulan dengan satuan yang benar

Tuliskan hasil akhir dengan:

- satuan meter,
- pembulatan wajar,
- konteks jawaban.

Contoh:

Tinggi tiang bendera $\approx$... meter.**Picture 10. ChatGPT Conversation of Group 4 – Strategy Determination Indicator**

The answer sheet of Group 4 presents a more comprehensive strategy than the framework provided by ChatGPT. The students added a visualization step by sketching a labeled right triangle, a unit identification step to ensure measurement consistency, and a final correction step that accounts for the observer's eye height. These three additional elements do not appear in the referenced ChatGPT conversation, demonstrating that the students developed a more complete strategy based on their own conceptual understanding, synthesized with information obtained from ChatGPT. Walter (2024) emphasizes that true artificial intelligence literacy means that students use technology as a tool to expand their thinking horizons, rather than merely as a shortcut to answers, and Group 4 concretely demonstrates this literacy.

4. Cross-Category Synthesis of Critical Thinking Indicators

Findings regarding the strategy determination indicator provide very rich insights into cognitive differences across categories. In Group 4, the resulting strategy is not merely a sequence of mechanical steps but reflects integrated conceptual understanding: visualization of a right triangle, selection of ratios based on the available sides, execution of calculations while considering the required precision, and final correction based on real-world conditions. In Group 2, the resulting strategy is more concise but still demonstrates conscious step selection. In Group 1, the written strategy is a verbatim copy of the ChatGPT step structure, without any indication that students understand why each step needs to be carried out. These differences demonstrate that the strategy determination indicator is the most comprehensive test of critical thinking because it requires the integration of all conceptual understanding that has been built through previous indicators, and serves as the clearest distinction between students who truly think critically and those who merely follow procedures.

A cross-category comparative analysis reveals consistent patterns that reinforce the findings above. In the identification indicator, artificial intelligence is proven to play a positive role for all students without exception in helping them understand the structure of the problem. However, the quality of identification produced differs significantly: high-ability students use ChatGPT to enrich identification that they have independently initiated, moderate-ability students perform independent identification which is then verified with ChatGPT, while low-ability students rely on ChatGPT to generate the entire identification process. This supports the statement of Alamsyah (2025) that artificial intelligence can make learning more reflective, but only if students actively evaluate and reprocess the information they receive, rather than merely consuming it passively.

In the justification indicator, the quality of students' explanations is strongly influenced by the type of questions posed to ChatGPT. High-ability students who ask exploratory questions such as why tangent is used instead of sine gain deeper understanding and are able to develop justifications that go beyond ChatGPT responses by adding arguments regarding the unavailability of the hypotenuse. Moderate-ability students who ask confirmatory questions obtain adequate explanations but do not develop them further. Low-ability students who only request complete answers do not obtain justifications that are truly understood, even though they are able to write them down. This phenomenon confirms the findings of Agustinasari and Fiqr (2025) that the effectiveness of artificial intelligence in improving logical thinking depends on students' initiative to explore more deeply. In the inference indicator, the measurable difference between the value of $\tan 34$ degrees used by Group 4 (0.674) and ChatGPT (0.6745) serves as the strongest empirical evidence that authentic inference processes only occur in students who position themselves as active agents in the calculation process, rather than passive consumers of ChatGPT outputs. The clarification and strategy determination indicators require initiative that entirely comes from the students: without intrinsic motivation to question the validity of results and model assumptions, these two indicators will never be authentically fulfilled even if ChatGPT is able to provide very comprehensive explanations.

Comparing the findings of this study with the global context of artificial intelligence use in mathematics education yields an interesting perspective. Gleneagles et al. (2024) reported that East Asian countries that have integrated artificial intelligence into mathematics learning show significant improvements in learning outcomes, but without distinguishing whether these improvements are accompanied by the development of authentic critical thinking skills. Tulak et al. (2024) found improvements in mathematics learning outcomes through AI-based adaptive assessment, but did not examine whether students truly understand the concepts behind the generated answers. This study contributes the perspective that the measure of success in integrating artificial intelligence in mathematics needs to be expanded beyond conventional learning outcomes, to include the dimension of the quality of critical thinking processes reflected in the synchronization between ChatGPT interactions and students' actual responses, a dimension that can only be measured through an in-depth qualitative approach that is sensitive to the nuances of cognitive processes.

Overall, synchronization analysis produces three patterns that can be clearly identified and show high consistency across problems and indicators. Group 1 shows a total-replica synchronization pattern in which the actual answers are direct copies of ChatGPT responses without meaningful cognitive transformation. Groups 2, 3, and 5 show a partial-adaptive synchronization pattern in which students adopt elements of ChatGPT responses but with limited selection and adaptation ability. Group 4 shows a transformative-critical synchronization pattern in which students consistently process, select, develop, and even correct information from ChatGPT based on conceptual understanding that has been

independently constructed. The gradation of these three patterns is not determined by differences in access to ChatGPT, but by differences in metacognitive awareness and depth of learning orientation. These findings strengthen and at the same time provide nuance to the study of Ratnawati et al. (2024), which found a positive impact of ChatGPT on students' analytical abilities, by showing that the impact is not homogeneous but highly dependent on how students position themselves in dialogue with technology. The most important theoretical implication is the need to develop an artificial intelligence literacy framework specific to mathematics learning that includes four dimensions: the ability to ask exploratory questions, the ability to independently verify and validate responses, the ability to integrate ChatGPT information with existing conceptual understanding, and the ability to identify limitations and assumptions in artificial intelligence responses.

The findings regarding these three synchronization patterns have significant implications for the design of artificial intelligence-based mathematics learning. If teachers design learning without considering the heterogeneity of students' synchronization patterns, then artificial intelligence will only benefit students who already have high metacognitive awareness (high category), while providing no significant benefit, and even potentially disadvantaging low-ability students who tend to use it as an answer-generating machine. Therefore, pedagogical scaffolding is needed to explicitly guide low- and moderate-ability students to transition from replica synchronization patterns to partial-adaptive patterns, and eventually to transformative-critical patterns. This scaffolding can take the form of structured guidelines for using ChatGPT, such as requiring students to ask at least three different questions before writing their answers, or an independent verification protocol in which students must perform at least one independent calculation before comparing their results with ChatGPT. Agustina and Suharya (2024) emphasize that effective integration of artificial intelligence requires careful pedagogical design, not merely the provision of technological access.

This study also contributes a new perspective on the assessment of critical thinking skills in the context of artificial intelligence-based learning. Conventional assessment that only focuses on the correctness of final answers is no longer adequate when students have access to artificial intelligence that can easily generate correct answers. The synchronization analysis developed in this study, namely systematically comparing the content of students' actual answers with the ChatGPT responses they use, offers a more authentic and sensitive assessment approach to the actual critical thinking process. This approach aligns with the principles of authentic assessment, which emphasize evaluating the process rather than merely the product. In addition, measurable differences such as the tan values used (0.674 vs 0.6745) and the addition of elements not present in ChatGPT responses can serve as concrete indicators to distinguish students who think critically from those who merely copy. Thus, this study not only provides descriptive findings about the relationship between artificial intelligence and critical thinking, but also offers an analytical methodology that can be adapted by teachers as a formative assessment instrument in technology-based mathematics learning.

Methodologically, this study also shows that synchronization analysis between artificial intelligence interactions and students' actual responses is a valid and sensitive approach for measuring the quality of critical thinking in the context of technology-based learning. Unlike conventional critical thinking tests that measure final products, synchronization analysis allows researchers and teachers to observe the actual cognitive processes that occur during student interaction with artificial intelligence. Measurable differences such as the decimal values used, the addition of elements not requested, and the

selection of assumptions different from those presented by ChatGPT become empirical traces indicating where and to what extent students' critical thinking truly operates authentically. This approach can be further developed as a technology-based formative assessment instrument that helps teachers precisely identify each student's position within the synchronization pattern spectrum, so that pedagogical interventions can be more targeted, personalized, and responsive to individual learning needs in an educational era that is increasingly integrated with artificial intelligence.

CONCLUSION

Based on the results of the study and the synchronization analysis between students' actual answers and their ChatGPT conversations, it can be concluded that the use of artificial intelligence influences the critical thinking skills of Grade X students at SMK Wikrama 1 Jepara in trigonometric comparison material through three qualitatively different synchronization patterns. First, high-ability students (Group 4) demonstrate a transformative-critical synchronization pattern: each ChatGPT response is processed, selected, developed, and in some cases corrected based on independent understanding, resulting in actual answers that are measurably different and more comprehensive than the ChatGPT responses. The difference in the value of $\tan 34^\circ$ (0.674 vs 0.6745), the addition of arguments regarding the unavailability of the hypotenuse, the correction of the observer's eye height, and additional visualization steps serve as concrete evidence of this pattern. Second, moderate-ability students (Groups 2, 3, and 5) demonstrate a partial-adaptive synchronization pattern: some critical thinking indicators begin to be fulfilled authentically, particularly identification and justification, but the ability for deeper clarification and independent strategy development remains limited. Third, low-ability students (Group 1) demonstrate a total-replica synchronization pattern: their actual answers are direct copies of ChatGPT responses without meaningful cognitive transformation, creating an illusion of understanding that is not grounded in genuine critical thinking processes.

The main finding of this study emphasizes that the effectiveness of artificial intelligence in supporting critical thinking is not determined by access to technology, but rather by students' learning orientation and metacognitive awareness in using it reflectively. Artificial intelligence positioned as a trigger for conceptual exploration and a dialogic partner has been proven to produce significantly higher levels of critical thinking compared to artificial intelligence positioned merely as an answer-generating tool. The practical implication is the need for teachers to design learning activities that explicitly guide students to pose exploratory questions to ChatGPT, independently verify responses, develop answers beyond those provided by the system, and identify the underlying assumptions in ChatGPT responses. Future research is recommended to develop and test an artificial intelligence literacy framework specifically for mathematics learning at the vocational high school level, including designing guidelines for using ChatGPT that encourage transformative-critical synchronization patterns across all levels of student ability.

The limitations of this study need to be acknowledged to provide proper context in interpreting the findings. First, the study was conducted in a single school with one class, so the generalizability of the findings needs to be tested through studies with a broader scope. Second, this study did not control for students' prior abilities before using ChatGPT, so it cannot be determined whether differences in synchronization patterns are influenced by other variables such as reading ability, learning motivation, or prior experience with artificial intelligence. Third, the synchronization analysis in this study is qualitative in nature, so the assessment of whether an element of a student's answer represents an independent contribution or a copy from ChatGPT still contains a degree of researcher subjectivity, which needs to be mitigated through inter-rater reliability in future studies. Fourth, this study only

examines the use of ChatGPT in a textual context without considering other contextual factors such as interactions among group members, which may also influence the quality of the answers produced.

Despite these limitations, this study provides a meaningful contribution to the field of technology-based mathematics education. The concept of three synchronization patterns—total-replica, partial-adaptive, and transformative-critical—offers a new analytical framework that can be used by researchers and educational practitioners to understand and evaluate the quality of student interactions with artificial intelligence in a more nuanced way than merely measuring learning outcomes. For mathematics teachers, these findings provide practical guidance for designing pedagogical interventions that encourage students to move from replica patterns toward transformative-critical patterns, including providing exploratory questioning guidelines, requiring independent verification, and incorporating synchronization analysis as part of the assessment process. For researchers, this study opens avenues for the development of critical thinking assessment instruments in the context of AI-based learning that are more authentic and sensitive to the actual cognitive processes taking place, not only in trigonometric comparison topics but also in other abstract mathematical topics that require deep conceptual understanding.

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