Analyzing Students' Mathematical Communication Failure Through ChatGPT-Assisted Scaffolding Based on Cognitive Styles

Zulaika Daningtyas[a], Nizlel Huda[b], Syamsir Sainuddin[c]*

[abc] Master's Program in Mathematics Education, Universitas Jambi, Jambi, Indonesia

*Corresponding: dtyaszulaika@gmail.com

Journal eISSN: 3109-9327

Article history: received 07-05-2026, revised 07-06-2026, accepted 29-06-2026

Abstract

This study aims to analyze the forms of students' mathematical communication failure in sequences and series and to examine how ChatGPT functions as adaptive scaffolding for students with Field Dependent (FD) and Field Independent (FI) cognitive styles. This study employed a qualitative case study design involving four eleventh-grade students selected purposively based on the Group Embedded Figures Test (GEFT). Data were collected through mathematical communication tests, think-aloud protocols, and semi-structured interviews. The analysis was based on mathematical communication indicators proposed by the National Council of Teachers of Mathematics (NCTM) and Greenes and Schulman. During problem-solving activities, ChatGPT was used as an adaptive scaffolding tool by providing guiding questions, conceptual clarification, and reflective prompts rather than direct answers. The findings revealed that FD students experienced difficulties in symbolic formalization and connecting representations, whereas FI students tended to provide incomplete explanations and verification processes. ChatGPT-assisted scaffolding supported each cognitive style differently by helping FD students formalize mathematical ideas and encouraging FI students to explain and verify their reasoning more explicitly. These findings contribute to mathematics learning innovation by demonstrating how AI-based adaptive scaffolding can provide personalized support according to students' cognitive characteristics and improve mathematical communication during problem solving.

Keywords

Cognitive style, Mathematical communication, Scaffolding, ChatGPT, Sequences and series.

Introduction

Mathematical communication is considered an essential competency in 21st-century mathematics education because it supports students' mathematical literacy, reasoning, and understanding of abstract concepts. In international educational frameworks, mathematical communication is viewed as a structured process through which students express mathematical ideas, arguments, and reasoning in formal learning situations (OECD, 2021). Students who possess strong mathematical communication skills tend to be more capable of relating mathematical concepts to contextual situations and explaining problem-solving strategies coherently and systematically (OECD, 2019; Tong et al., 2021). Recent bibliometric evidence also confirms that mathematical communication has become an increasingly prominent research focus, indicating its central role in mathematics education development and its strong linkage with various instructional approaches and student competencies (Daningtyas et al., 2025).

However, empirical evidence indicates that students continue to experience considerable difficulties in mathematical communication. The results of the Programme for International Student Assessment (PISA) 2022 revealed that Indonesian students' mathematical literacy remains below the OECD average, particularly in interpreting mathematical information, explaining mathematical reasoning, and solving contextual problems. These findings suggest that many students still encounter challenges in communicating mathematical ideas effectively in meaningful mathematical situations. Similar evidence has also been reported in previous studies, which found that students often struggle to use mathematical symbols appropriately, explain reasoning systematically, and connect multiple representations such as tables, graphs, and diagrams (Rehman et al., 2023; Suhenda & Munandar, 2023). In addition, students' written mathematical explanations and arguments are frequently incomplete, fragmented, and insufficiently supported by logical reasoning (Lehmann & Lesley, 2025). These communication difficulties are particularly relevant to topics such as sequences and series, where students are required not only to identify numerical patterns but also to represent relationships symbolically, explain solution procedures, and justify mathematical conclusions.

Therefore, mathematical communication difficulties are not merely caused by procedural errors but also reflect students' inability to organize, interpret, and communicate mathematical thinking coherently.

Theoretically, mathematical communication is considered an integral part of mathematical thinking. NCTM (2020) emphasizes that mathematical communication involves the ability to express ideas clearly, use mathematical symbols accurately, and understand various mathematical representations. In line with this perspective, Sfard (2008) explained that learning mathematics occurs through participation in mathematical discourse, where students construct meaning through communication and interaction. Furthermore, Duval (2006) argued that mathematical understanding requires the coordination of multiple representations because students often experience difficulties when transforming intuitive ideas into formal mathematical language. Recent studies also indicate that many students still struggle to connect representations and communicate mathematical reasoning coherently during problem-solving activities (Planas & Pimm, 2024; Genç et al., 2025). Therefore, difficulties in mathematical communication may arise when students are unable to organize and transform their understanding into appropriate mathematical representations.

Besides representational aspects, students' mathematical communication is also influenced by individual cognitive characteristics, particularly cognitive styles. Field Dependent (FD) and Field Independent (FI) cognitive styles describe different ways students perceive, organize, and communicate information. According to Witkin (1973), students with an FD cognitive style tend to rely on external references and contextual cues when processing information. Consequently, they are more likely to express mathematical ideas using everyday language and contextual explanations rather than formal mathematical symbols and representations. In contrast, students with an FI cognitive style tend to process information analytically and independently, enabling them to organize mathematical procedures and construct symbolic representations more systematically. However, they often focus primarily on obtaining correct solutions and may provide limited explanations of the reasoning and verification underlying their procedures (Witkin, 1973; Ismaimuza et al., 2024). Therefore, cognitive styles influence not only students' problem-solving approaches but also how they express mathematical ideas, construct arguments, connect multiple representations, and communicate mathematical reasoning. Previous studies have similarly reported that FD and FI students demonstrate different characteristics of mathematical communication difficulties, particularly in constructing mathematical models, using mathematical symbols, and explaining solution processes (Salam & Khusna, 2025).

To address these challenges, scaffolding is considered an effective instructional strategy in mathematics learning. Based on Vygotsky's Zone of Proximal Development theory, scaffolding refers to temporary assistance provided to help students achieve higher levels of understanding through adaptive guidance (Vygotsky, 1978; Wood et al., 1976). Through appropriate support, students are encouraged to develop reasoning, organize ideas, and solve problems more independently. Previous studies have also reported that scaffolding can improve students' reasoning and mathematical communication abilities by helping them clarify concepts and express mathematical ideas more systematically (Çakar Özkan, 2022; Esparcia et al., 2024).

To address students' difficulties in mathematical communication, scaffolding can be integrated with digital technologies such as ChatGPT. Students who experience difficulties in expressing mathematical ideas, connecting representations, or explaining mathematical reasoning require adaptive support that provides guidance rather than direct answers. In this context, ChatGPT was selected because its interactive dialogue enables students to receive guiding questions, conceptual clarification, and metacognitive prompts according to their immediate learning needs. Such support is consistent with the principles of scaffolding, which emphasize temporary assistance to help learners gradually construct understanding independently.

Recent studies have shown that AI-based learning tools can support mathematics learning through adaptive feedback, reflective dialogue, and conceptual clarification (Wang et al., 2024; Wardat et al., 2023). In mathematics education, ChatGPT has the potential to function as adaptive scaffolding by providing guiding questions, metacognitive prompts, and structured assistance that help students organize and communicate their mathematical thinking more effectively (Huda et al., 2025; Hofer & Reinhold, 2025; Thomann & Deutscher, 2025; Pepin et al., 2025). A recent scoping review also confirms that ChatGPT is increasingly being explored as an instructional support tool in mathematics education because it facilitates mathematical reasoning, reflective learning, and student–AI interaction during problem solving (Pepin et al., 2025). Furthermore, empirical evidence indicates that ChatGPT-assisted scaffolding can strengthen students' metacognitive awareness when learning mathematical concepts (Huda et al., 2025). Therefore, in this study, ChatGPT is not positioned as a tool for providing solutions, but as an adaptive scaffolding medium that supports students in constructing, organizing, and communicating mathematical ideas more explicitly during problem-solving activities.

Nevertheless, previous studies have generally examined mathematical communication, cognitive styles, and scaffolding as separate areas of investigation. Although several studies have explored students' mathematical communication difficulties, they have rarely analyzed how these difficulties differ according to Field Dependent (FD) and Field Independent (FI) cognitive styles. Likewise, research on ChatGPT in mathematics education has primarily focused on improving learning outcomes, problem-solving, or metacognitive skills, with limited attention to its role as adaptive scaffolding for addressing students' mathematical communication failures. As a result, there is still limited understanding of how AI-assisted scaffolding can respond to different cognitive characteristics in supporting students' mathematical communication.

This gap is important because students with different cognitive styles experience different forms of communication difficulties, requiring different types of instructional support. Without understanding these differences, teachers may provide the same scaffolding strategies for all students, even though their communication needs are not identical. Therefore, adaptive scaffolding that considers students' cognitive characteristics is needed to support more effective mathematical communication.

The topic of sequences and series was selected as the research context because it requires students to identify numerical patterns, construct mathematical models, use symbolic representations, interpret tables or diagrams, and explain mathematical reasoning systematically. These characteristics make sequences and series an appropriate topic for examining students' mathematical communication processes and identifying communication failures across multiple representations.

Therefore, this study aims to first analyze the forms of students' mathematical communication failure in sequences and series based on Field Dependent and Field Independent cognitive styles and subsequently examine how ChatGPT-assisted scaffolding supports students in overcoming these communication difficulties. By addressing the identified research gap, this study contributes to mathematics education by extending the understanding of mathematical communication failure from a cognitive-style perspective and by providing empirical evidence regarding the adaptive pedagogical role of ChatGPT-assisted scaffolding in supporting personalized mathematics learning.

Methodology

This study employed a qualitative approach using an instrumental case study design to obtain an in-depth understanding of students' mathematical communication failure and the role of ChatGPT-assisted scaffolding in addressing these difficulties. An instrumental case study was selected because the focus of the study was not the individual students themselves but the phenomenon of mathematical communication failure viewed through different cognitive styles. The selected cases served as a means to explore how Field Dependent (FD) and Field Independent (FI) students experienced communication difficulties and how ChatGPT-assisted scaffolding supported their mathematical communication during problem-solving activities. This design enabled an in-depth exploration of students' thinking processes, representation patterns, and interactions with ChatGPT within authentic learning situations.

This study was conducted in a public Madrasah Aliyah in Jambi, Indonesia. Participants were selected using purposive sampling because qualitative case study research emphasizes obtaining rich and in-depth information rather than achieving statistical representation. The selection process was carried out in several stages. First, all eleventh-grade students completed the Group Embedded Figures Test (GEFT) to identify their cognitive styles. Second, students were grouped into Field Dependent (FD) and Field Independent (FI) categories based on their GEFT scores. Finally, four participants were selected, consisting of two FD students and two FI students, because they demonstrated clear cognitive style characteristics, were able to communicate their thinking during think-aloud and interview sessions, and were willing to participate throughout all stages of the study. In addition, the selected participants represented relatively similar mathematical achievement based on their recent mathematics learning outcomes, allowing the analysis to focus on differences associated with cognitive styles rather than differences in mathematical ability. The four participants were considered sufficient because the objective of this instrumental case study was to obtain an in-depth understanding of the phenomenon rather than to generalize the findings to a larger population.

Cognitive styles were identified using the Group Embedded Figures Test (GEFT) developed by Witkin (1973). The GEFT was administered individually under standardized testing procedures. Participants completed three sections of the test, in which they were required to identify simple geometric figures embedded within more complex figures. The first section served as practice and was not included in the final score, whereas the remaining two sections consisted of 18 scored items. Each correct answer received one point, resulting in a maximum score of 18. Following the commonly used classification proposed by Witkin (1973), students with GEFT scores of 0–11 were categorized as Field Dependent (FD), while those scoring 12–18 were categorized as Field Independent (FI). These classifications were subsequently used as the basis for selecting participants representing both cognitive style groups.

The primary instrument of this study was a written mathematical communication test in the form of essay questions on sequences and series topics. The test items were developed based on mathematical communication indicators proposed by the National Council of Teachers of Mathematics (NCTM) and Greenes and Schulman. The indicators included: (1) expressing mathematical ideas clearly, (2) using symbols and notation appropriately, (3) interpreting and connecting multiple representations, and (4) constructing logical conclusions.

Supporting instruments included think-aloud protocols and semi-structured interview guidelines. The think-aloud technique was used to capture students' real-time thinking processes while solving mathematical problems. Meanwhile, interviews were conducted to clarify students' written responses and explore their experiences during the ChatGPT-assisted scaffolding process. During the scaffolding stage, students accessed ChatGPT (GPT-4o, OpenAI) using their own smartphones through the ChatGPT application. Students were allowed to formulate their own prompts according to the difficulties they encountered while solving the mathematical problems, such as understanding concepts, determining mathematical models, interpreting symbols, or explaining solution procedures. Before the activity, the researcher instructed students to use ChatGPT as a learning support tool rather than a source of direct answers. Students were encouraged to ask for hints, conceptual explanations, and guiding questions instead of requesting complete solutions. Throughout the activity, the researcher monitored students' interactions with ChatGPT to ensure that the AI functioned as adaptive scaffolding rather than as an answer provider. All prompts submitted by the students and the corresponding ChatGPT responses were documented through screenshots and chat history records, which were subsequently analyzed together with the students' written responses, think-aloud protocols, and interview transcripts.

Data collection was conducted in three stages. First, students completed the GEFT to determine their cognitive style categories. Second, students worked on the mathematical communication test using the think-aloud method. During the problem-solving process, students were allowed to interact with ChatGPT when they encountered difficulties. In this study, ChatGPT functioned as adaptive scaffolding by providing guiding questions, conceptual clarification, and reflective prompts without directly giving final answers.

Third, semi-structured interviews were conducted after the test session to confirm findings and obtain deeper information regarding students' mathematical communication processes and their responses to ChatGPT-assisted scaffolding. All activities were documented through audio recordings and field notes to support data accuracy. The data were analyzed descriptively using qualitative analysis techniques, including data reduction, data display, and conclusion drawing. The analyzed data consisted of students' written responses, think-aloud transcripts, interview results, and interactions with ChatGPT. Mathematical communication failure was identified by comparing students' performance with the four mathematical communication indicators adapted from the National Council of Teachers of Mathematics (NCTM) and Greenes and Schulman: (1) expressing mathematical ideas clearly, (2) using mathematical symbols and notation appropriately, (3) interpreting and connecting multiple representations, and (4) constructing logical mathematical conclusions. A communication failure was identified when students were unable to meet one or more of these indicators, such as providing incomplete explanations, using inappropriate mathematical symbols, failing to connect representations, or drawing unsupported conclusions.

To increase the credibility of the analysis, findings from students' written responses were triangulated with think-aloud protocols, interview transcripts, and ChatGPT interaction records. The analysis then compared the patterns of mathematical communication failure between Field Dependent (FD) and Field Independent (FI) students, as well as the changes in students' communication after receiving ChatGPT-assisted scaffolding.

To ensure the trustworthiness of the findings, triangulation of techniques and data sources was applied. The researchers compared data obtained from written tests, think-aloud protocols, interviews, and ChatGPT interaction records. Member checking was also conducted during interviews to confirm the accuracy of participants' responses and interpretations. These strategies were used to enhance the credibility and consistency of the research findings.

Results

This section presents the findings of the study based on the research objectives, namely to identify the forms of students' mathematical communication failure in sequences and series topics and to examine the role of ChatGPT-assisted scaffolding based on Field Dependent (FD) and Field Independent (FI) cognitive styles. The findings were obtained from mathematical communication tests, think-aloud protocols, interviews, and students' interactions with ChatGPT during problem-solving activities.

The analysis of students' written responses, think-aloud protocols, and interview data revealed differences in mathematical communication characteristics between Field Dependent (FD) and Field Independent (FI) students across the four communication indicators. A summary of these findings is presented in Table 1.

Table 1. Summary of Students' Mathematical Communication Failure Characteristics

Mathematical Communication Indicators	FD Students	FI Students	Data Source
Expressing mathematical ideas	Narrative and less systematic	More structured but brief	WR, TA, INT
Use of symbols and notation	Inconsistent and incomplete	Appropriate but minimally explained	WR, TA, INT
Connecting representations	Weak connection between representations	Adequate but not fully elaborated	WR, TA, INT
Constructing logical conclusions	Descriptive and unsupported	Conclusions written without verification explanation	WR, TA, INT

Note. WR = written responses to the mathematical communication test; TA = think-aloud protocols collected during problem-solving activities; INT = semi-structured interview data. Overall, the four mathematical communication indicators revealed different patterns according to students' cognitive styles. FD students tended to express mathematical ideas narratively, use symbols inconsistently, and experience difficulties in connecting multiple representations. In contrast, FI students generally demonstrated more systematic symbolic representations and procedures but provided limited explanations of mathematical reasoning and verification. These patterns were consistently identified across students' written responses, think-aloud protocols, and interview data.

Based on Table 1 and the triangulation of written responses (WR), think-aloud protocols (TA), and interview data (INT), both FD and FI students demonstrated weaknesses in mathematical communication, although the forms of failure differed according to their cognitive styles. FD students primarily experienced difficulties in symbolic formalization and connecting multiple representations, whereas FI students generally demonstrated more systematic symbolic representations but encountered limitations in explicitly explaining mathematical reasoning and verification processes.

Mathematical Communication Failure of FD Students

Furthermore, students with a Field Dependent (FD) cognitive style tended to experience mathematical communication failure primarily in the aspects of symbolic formalization and representation. Analysis of the written responses, think-aloud protocols, and interview data indicates that this tendency emerged because FD students relied more on contextual understanding than on formal mathematical language when expressing their ideas. Although they were able to recognize the arithmetic sequence pattern intuitively, they often organized their solutions using everyday language and visual representations before translating them into mathematical symbols. Consequently, mathematical formulas and symbolic representations were either omitted or used inconsistently, resulting in incomplete mathematical communication. An example of an FD student's written response is presented in Figure 1.

Based on Figure 1, FD1 began by describing the problem context using everyday language before representing the situation through a sketch of the planting holes, a distance table, and a simple graph. These representations indicate that the student recognized the arithmetic growth pattern and understood that the distance between consecutive holes increased by 1.5 meters. The student also attempted to determine the twentieth term by writing the arithmetic sequence formula, $U_n = a + (n-1)b$, and correctly substituted the values to obtain $U_{20} = 38.5$. However, the mathematical communication remained incomplete because the different representations were not explicitly connected through formal mathematical reasoning. Although a diagram, table, graph, and formula were presented, the student did not explain how these representations supported one another in constructing the mathematical model. Instead, the final explanation relied primarily on descriptive sentences, such as stating that "the distance keeps increasing by 1.5 meters" and that the total distance was obtained by doubling the sum because Mr. Budi walked back and forth. The student also calculated the total distance by manually adding each term of the sequence rather than communicating the mathematical relationship through the arithmetic series formula. This indicates that the student understood the problem context but experienced difficulty transforming contextual understanding into coherent symbolic and representational mathematical communication. This interpretation is consistent with the interview findings. FD1 explained:

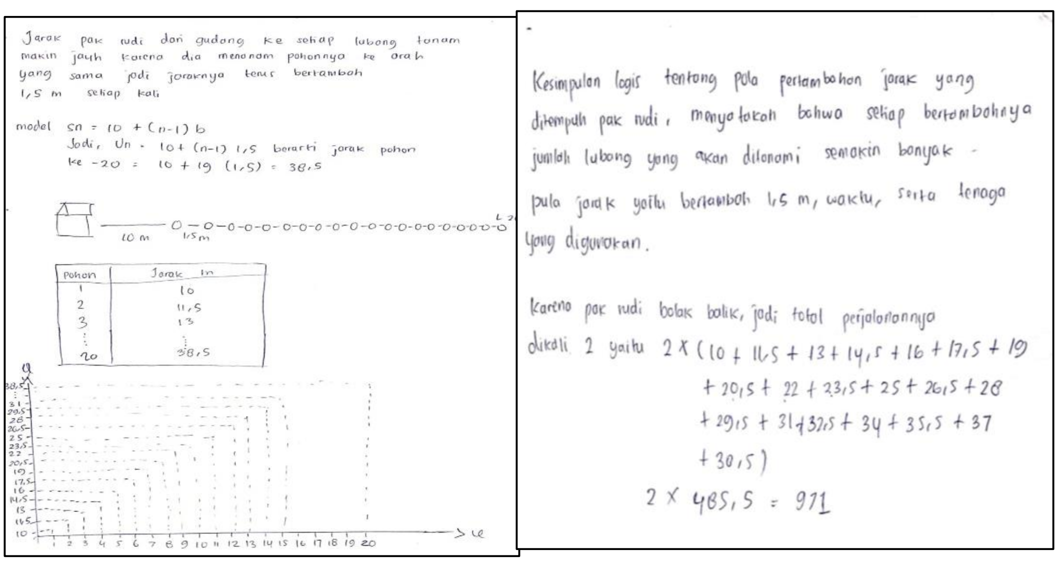

Figure 1 presents the written response of subject FD1 in solving the mathematical communication problem.

FD1 : "I usually explain it using ordinary language first, and then I use the formula."

The student also admitted experiencing difficulties in using mathematical symbols consistently:

FD1 : "I understand a little about symbols such as Un and Sn, but sometimes I still confuse them."

These findings indicate that FD students tended to understand mathematical problems contextually; however, they experienced difficulties in organizing and formalizing mathematical ideas systematically. Visual representations such as diagrams and tables were considered more helpful than symbolic representations. In addition, FD students also experienced difficulties in connecting multiple representations simultaneously. S2FD explained:

FD1 : "The difficult part is connecting everything together. I can still connect the picture and the table, but when I also have to use formulas, I sometimes get confused."

These findings indicate that FD students relied more on contextual understanding and visual representations rather than formal symbolic communication. As a result, the mathematical explanations provided tended to be more descriptive and were not sufficiently supported by explicit mathematical reasoning.

Mathematical Communication Failure of FI Students

In contrast to FD students, who relied more on contextual understanding and visual representations, students with a Field Independent (FI) cognitive style demonstrated a more analytical approach in constructing mathematical models and performing calculations. Analysis of the written responses, think-aloud protocols, and interview data indicates that this characteristic emerged because FI students tended to focus on procedural efficiency and obtaining correct solutions rather than explicitly communicating the reasoning underlying each solution step. Consequently, they were able to organize mathematical information systematically and apply appropriate formulas; however, they rarely explained why a particular formula was selected, how different representations were connected, or how the final conclusions were verified. As a result, although their solutions were mathematically correct, their mathematical communication remained incomplete, particularly in terms of reasoning and verification.

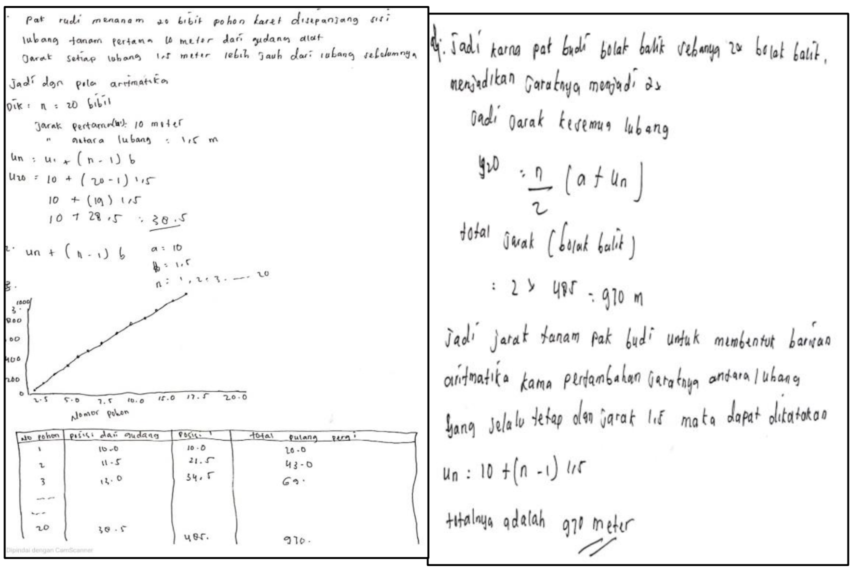

Figure 2. Written Response of a Field Independent (FI) Student in the Mathematical Communication Test

Based on Figure 2, FI1 organized the mathematical information systematically by first identifying the arithmetic sequence pattern, determining the first term ($a = 10$) and common difference ($b = 1.5$), and applying the arithmetic sequence and series formulas appropriately to obtain the required results. The student also constructed supporting representations in the form of a graph and a table, indicating an analytical approach to organizing mathematical information before performing calculations.

Analysis of the written response indicates that these characteristics emerged because the student prioritized procedural accuracy and efficiency during problem solving. Rather than relying on contextual descriptions, FI1 immediately translated the problem into mathematical symbols and formulas and proceeded directly to the calculation stage. However, although the mathematical model and calculations were correct, the communication remained incomplete because the student did not explicitly explain why the formulas were selected or how the graph, table, and symbolic model were conceptually related. The representations were presented as separate components of the solution instead of being integrated into a coherent mathematical explanation. Consequently, the final conclusion focused primarily on the numerical result rather than on the reasoning that justified the solution. This tendency was also reflected in the interview findings. FI1 explained:

FI1	: "I directly used the formula because, in my opinion, the important thing was getting the correct answer."

In addition, the student emphasized efficiency in solving the problem rather than explicitly explaining the thinking process. Although the symbolic representations and calculations were well organized, the verification process and mathematical reasoning were not communicated in depth. These findings indicate that FI students possessed relatively strong analytical abilities in constructing mathematical models and completing calculations. However, their mathematical communication remained limited to presenting procedures and final answers. As a result, explanations regarding the reasons for using particular concepts, the relationships among representations, and the verification process were not communicated comprehensively.

The Role of ChatGPT-Assisted Scaffolding

After identifying the forms of mathematical communication failure among FD and FI students, the study continued by analyzing the role of ChatGPT-assisted scaffolding in supporting students during mathematical problem-solving activities. At this stage, students were given equivalent problems with different contexts and were allowed to use ChatGPT whenever they experienced difficulties in understanding concepts, constructing mathematical models, or explaining solution procedures.

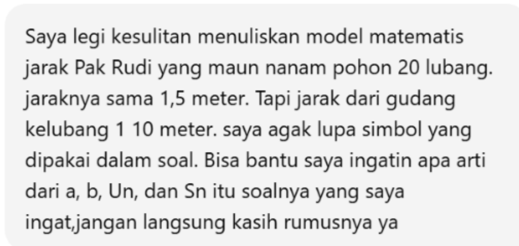

Figure 3. Prompts and ChatGPT Interactions of FD Students During the Scaffolding Process

Based on Figure 3, the prompt submitted by FD1 indicates that the student primarily sought conceptual clarification rather than direct solutions. Instead of requesting the final answer, the student asked ChatGPT to explain the meanings of mathematical symbols, including a, b, U_n, and S_n, and to provide guidance in constructing an appropriate mathematical model for the given problem. The prompt also explicitly requested that ChatGPT avoid giving the formula immediately, demonstrating the student's preference for understanding the underlying concepts before proceeding with the solution.

Analysis of the interaction suggests that this pattern emerged because FD1 experienced difficulties in transforming contextual information into formal mathematical notation. Although the student understood the problem situation, uncertainty regarding the meanings and functions of mathematical symbols prevented the construction of an appropriate mathematical model. Consequently, the student used ChatGPT primarily as a source of conceptual support to bridge contextual understanding with formal mathematical representations rather than as a tool for obtaining direct answers. Examples of prompts and ChatGPT interactions from FI students during the scaffolding process are presented in Figure 4.

saya sudah membuat grafiknya, apakah sudah sesuai sama soalnya. Ini jaraknya naik terus kan, tapi ini baru jarak satu arah, kan?

Figure 4. Prompts and ChatGPT Interactions of FI Students During the Scaffolding Process

Based on Figure 4, FI1 used ChatGPT primarily to verify the correctness of the solution rather than to seek conceptual explanations. The student asked whether the graph that had been constructed matched the problem context and confirmed whether it represented only the one-way distance. This prompt indicates that FI1 had already developed the mathematical model independently but still required confirmation regarding the accuracy and interpretation of the representation. This interaction reflects the analytical tendency of FI students, who emphasize procedural correctness and verification rather than conceptual clarification. Consequently, ChatGPT functioned as a reflective tool that supported students in evaluating the appropriateness of their mathematical representations before drawing conclusions.

During the scaffolding process, ChatGPT functioned as adaptive support through guiding questions, conceptual clarification, and reflective prompts. For FD students, ChatGPT assisted in explaining the relationships among mathematical symbols and solution procedures more systematically. Meanwhile, for FI students, ChatGPT encouraged reflective thinking by prompting students to recheck the reasons for using formulas and the accuracy of their calculations.

The impact of scaffolding could be observed from students' responses after interacting with ChatGPT. Students demonstrated more consistent use of symbols, clearer representations, and more structured mathematical explanations compared to their previous responses. Examples of ChatGPT responses to the prompts submitted by FD students are presented in Figure 5.

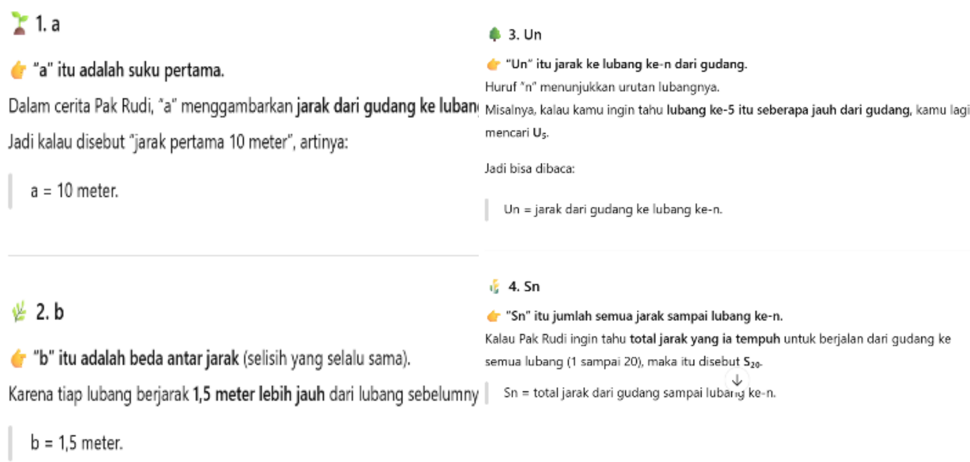

Figure 5. ChatGPT's Response to the Field Dependent Student's Prompt

Based on Figure 5, ChatGPT responded by providing conceptual explanations of the mathematical symbols a, b, U_n, and $S_n$in a gradual and structured manner without directly presenting the final solution. Instead of immediately introducing formulas, ChatGPT first explained the meaning and function of each symbol within the context of the problem. This approach enabled the student to relate the contextual situation to formal mathematical notation before proceeding to mathematical modeling.

The response indicates that ChatGPT functioned as conceptual scaffolding by reducing students' uncertainty regarding mathematical notation and guiding them to construct meaning independently. Rather than providing procedural answers, the system encouraged the student to understand the relationships among concepts, which is consistent with the cognitive characteristics of FD students who tend to rely on contextual explanations before using symbolic representations.

ChatGPT's responses functioned as conceptual scaffolding by providing gradual explanations without directly giving the final answer. Through guiding questions and symbolic clarification, students were encouraged to understand the relationships among mathematical concepts before proceeding to the calculation stage. These findings indicate that FD students required more explicit and structured support in transforming contextual understanding into formal mathematical communication.

1. **Di grafikmu, jarak yang kamu plot itu jarak dari gudang ke lubang saja, atau sudah jarak PP (pergi–pulang)?**
   Coba cek lagi: setiap kali Pak Rudi menanam satu bibit, apa dia hanya berjalan *ke* lubang atau *ke dan kembali* ke gudang?
2. **Kalau baru jarak satu arah**, apa konsekuensi yang terjadi kalau kamu ingin menggambarkan **total jarak tempuh** ke setiap lubang?
   (Petunjuk kecil: pikirkan apakah kamu perlu mengalikan sesuatu, atau menambah sesuatu.)
3. Lalu coba lihat grafikmu:
   Apakah kenaikan jaraknya selalu bertambah sebesar angka yang sama?
   Kalau iya, berarti grafikmu sudah mengikuti pola yang ditanyakan.

Figure 6. ChatGPT's Response to the Field inpendent Student's Prompt

Based on the responses shown in Figure 6, FI students used ChatGPT more as a reflective tool to verify procedures and ensure the accuracy of their solution steps. Although FI students were able to determine formulas independently, they still experienced limitations in explaining reasoning and verification processes explicitly. Therefore, ChatGPT-assisted scaffolding supported FI students through reflective prompts that encouraged them to recheck calculations and explain the reasons for using particular solution procedures more systematically.Discussion and Conclusion

The findings of this study indicate that students' mathematical communication failure is closely related to their cognitive styles, particularly Field Dependent (FD) and Field Independent (FI). FD students tended to experience difficulties in symbolic formalization and connecting multiple mathematical representations, whereas FI students demonstrated limitations in explaining reasoning and verification processes explicitly. These differences reflect variations in how students process, organize, and externalize mathematical thinking.

From the perspective of cognitive style theory, these findings support Witkin's view that FD students rely more on contextual understanding and external guidance, while FI students tend to be more analytical and independent in processing information. Recent studies have also shown that differences in cognitive styles influence students' abilities to organize representations, construct mathematical arguments, and communicate thinking processes systematically (Ismaimuza et al., 2024; Salam & Khusna, 2025). This explains why FD students often expressed ideas narratively without clear mathematical representations, whereas FI students focused more on procedures and final answers rather than communicating reasoning comprehensively.

The findings also support Sfard's discourse theory, which emphasizes that learning mathematics involves participation in mathematical discourse. In this study, several students were able to obtain correct answers but were still unable to communicate mathematical reasoning systematically. Recent studies further indicate that mathematical communication is not only related to obtaining final answers but also to students' ability to explain ideas, construct arguments, and connect mathematical representations meaningfully (Planas & Pimm, 2024; Genç et al., 2025). In addition, Duval's representation theory highlights the importance of coordinating multiple representations in mathematical understanding. Students' difficulties in transforming intuitive understanding into formal mathematical language contributed significantly to mathematical communication failure, particularly among FD students.

Furthermore, the implementation of ChatGPT-assisted scaffolding demonstrated its potential as adaptive support in mathematics learning. Through guiding questions, conceptual clarification, and reflective prompts, ChatGPT helped students organize ideas, evaluate solution procedures, and communicate reasoning more explicitly. These findings are consistent with Vygotsky's scaffolding concept, which emphasizes the importance of adaptive assistance in helping learners achieve higher levels of understanding. Recent studies have also shown that the use of AI in mathematics education can support reflective learning, enhance students' metacognitive engagement, and provide more personalized feedback according to students' learning needs (Wang et al., 2024; Hofer & Reinhold, 2025; Thomann & Deutscher, 2025).

The findings of this study imply that mathematics instruction should not only focus on procedural accuracy but also provide opportunities for students to explain reasoning, connect multiple representations, and communicate mathematical ideas systematically. In this context, AI-based scaffolding such as ChatGPT has the potential to support more responsive and personalized mathematics learning according to students' cognitive characteristics. In addition, teachers need to design learning activities that accommodate differences in students' cognitive styles so that mathematical communication skills can develop more optimally.

Conclusion

This study demonstrates that mathematical communication failure should not be viewed as a single or uniform learning difficulty. Instead, it reflects different ways in which students organize, represent, and communicate mathematical thinking according to their cognitive styles. These findings suggest that students may arrive at correct mathematical solutions while still experiencing communication failure because they are unable to express reasoning, connect representations, or justify mathematical ideas explicitly. Therefore, assessing mathematical communication should extend beyond evaluating procedural accuracy and final answers to include the quality of students' mathematical explanations and representations.

The findings also demonstrate that ChatGPT-assisted scaffolding has the potential to serve as adaptive pedagogical support rather than merely an AI-based answering tool. By providing conceptual clarification for Field Dependent students and reflective prompts for Field Independent students, ChatGPT supported different aspects of mathematical communication according to students' cognitive needs. This indicates that AI-assisted scaffolding can contribute to more personalized mathematics learning by accommodating variations in students' ways of thinking and communicating mathematical ideas.

Theoretically, this study extends current understanding of mathematical communication by integrating cognitive style theory with AI-assisted scaffolding into a single analytical framework. Practically, the findings suggest that mathematics teachers should design communication-oriented learning activities that provide differentiated scaffolding according to students' cognitive characteristics instead of employing uniform instructional support.

This study was limited to four participants and focused only on sequences and series. Future studies are recommended to involve broader participant groups, different mathematical topics, and various AI-assisted learning environments to further investigate how adaptive scaffolding can strengthen mathematical communication across diverse learner characteristics.

Declarations

Competing Interests

The authors declare that there is no conflict of interest related to this research and publication.

Data Availability

The data used in this study are available from the corresponding author and can be accessed upon reasonable request.

Acknowledgement

The authors would like to express their sincere gratitude to MAN 2 Kota Jambi for granting permission and support during the research process. Special thanks are also extended to all students who participated in this study for their cooperation and contribution. The authors also appreciate the guidance, suggestions, and encouragement provided by supervisors and colleagues in the Mathematics Education Department, Universitas Jambi, throughout the completion of this research.

Authors' Contributions

Zulaika Daningtyas conducted the research, collected and analyzed the data, and prepared the manuscript. Nizlel Huda supervised the research process and provided suggestions for improving the manuscript. Syamsir Sainuddin contributed to data interpretation and manuscript revision. All authors have read and approved the final version of the manuscript.

References

Çakar Özkan, E. (2022). Scaffolding as teachers' guidance role in the context of constructivist learning Approach. Journal of Educational Issues, 8(1), 399. https://doi.org/10.5296/jei.v8i1.19690

Daningtyas, Z., Huda, N., & Sainuddin, S. (2025). Mapping research trends in mathematical communication: A bibliometric review using VOSviewer. Journal of General Education and Humanities, 4(4), 1913–1928. https://doi.org/10.58421/gehu.v4i4.775

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics, 61*(1–2), 103–131. https://doi.org/10.1007/s10649-006-0400-z

Esparcia, J., López, M., & García, R. (2024). Scaffolding strategies in mathematics learning: Supporting mathematical communication and reasoning. *Journal of Mathematics Education Research, 16*(2), 88–102. https://doi.org/10.5281/zenodo.11185028

Genç, M., Yıldız, A., & Kaya, S. (2025). Students' mathematical communication and representation skills in problem-solving activities. *Mathematics Education Review, 37*(1), 45–61.

Hofer, S. I., & Reinhold, F. (2025). Scaffolding of learning activities: Aptitude-treatment interaction effects in math? Learning and Instruction, 99, 102177. https://doi.org/10.1016/j.learninstruc.2025.102177

Huda, N., Anwar, K., . N., & Kurniawan, W. (2025). Chatgpt scaffolding in supporting metacognition for limit concepts in guided inquiry mathematics learning. Journal of Information Technology Education: Research, 24, 038. https://doi.org/10.28945/5645

Ismaimuza, D., Nusantara, T., & Parta, I. N. (2024). Cognitive styles and students' mathematical communication in problem-solving. *Journal on Mathematics Education, 15*(1), 85–100.http://doi.org/10.55463/issn.1674-2974.51.8.1

Lehmann, T., & Lesley, K. (2025). Written mathematical explanations and students' argumentation quality in secondary mathematics classrooms. *International Journal of STEM Education, 12*(1), 1–18. https://doi.org/10.1007/s10763-025-10590-7

NCTM. (2020). *Principles to actions: Ensuring mathematical success for all*. National Council of Teachers of Mathematics.

OECD. (2019). *PISA 2018 assessment and analytical framework*. OECD Publishing. https://doi.org/10.1787/b25efab8-en

OECD. (2021). *21st-century readers: Developing literacy skills in a digital world*. OECD Publishing. https://doi.org/10.1787/a83d84cb-en

Pepin, B., Buchholtz, N., & Salinas-Hernández, U. (2025). A scoping survey of chatgpt in mathematics education. Digital Experiences in Mathematics Education, 11(1), 9–41. https://doi.org/10.1007/s40751-025-00172-1

Planas, N., & Pimm, D. (2024). Mathematical communication and discourse in contemporary mathematics classrooms. *Educational Studies in Mathematics, 115*(2), 201–219. https://doi.org/10.1007/s11858-023-01497-0

Rehman, A., Abdullah, N., & Karim, S. (2023). Students' difficulties in mathematical communication and representation. *Journal of Educational Research in Mathematics, 11*(3), 145–159. https://doi.org/10.1057/s41599-023-01914-5

Salam, R., & Khusna, H. (2025). Differences in mathematical communication between field dependent and field independent students. *Journal of Mathematics and Science Education, 13*(1), 22–34. https://dx.doi.org/10.26594/jmpm.v10i1.5605

Sfard, A. (2008). *Thinking as communicating: Human development, the growth of discourses, and mathematizing*. Cambridge University Press.

Suhenda, A., & Munandar, D. R. (2023). Students' mathematical communication difficulties in connecting multiple representations. *Jurnal Pendidikan Matematika, 17*(1), 55–68. http://10.31949/educatio.v9i2.5049

Thomann, H., & Deutscher, V. (2025). Scaffolding through prompts in digital learning: A systematic review and meta-analysis of effectiveness on learning achievement. Educational Research Review, 47, 100686. https://doi.org/10.1016/j.edurev.2025.100686

Tong, D. H., Loc, N. P., & Uyen, B. P. (2021). Enhancing mathematical communication through contextual learning. *European Journal of Educational Research, 10*(2), 745–756. https://doi.org/10.12973/eu-jer.10.3.1287

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wang, X., Li, Y., & Zhao, H. (2024). Artificial intelligence in mathematics education: Adaptive feedback and reflective learning. *Computers & Education, 205*, 104902. https://doi.org/10.1016/j.eswa.2024.124167

Wardat, Y., Tashtoush, M. A., & AlAli, R. (2023). ChatGPT and mathematics education: Opportunities and challenges for teaching and learning. *Education Sciences, 13*(9), 1–17. https://doi.org/10.29333/ejmste/13272

Witkin, H. A. (1973). The role of cognitive style in academic performance and learning. *Research Bulletin*, 73–11.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89–100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x