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Patterns of Student Thinking Interaction in Group Discussion: The Effect of Explorative Interaction on Understanding Statistical Concepts

Syarifudin[1*], Abd. Haris[1], Nurrahmah[1]
[1]Mathematics Education, STKIP Taman Siswa Bima, Indonesia
syarifudinsyarif745@gmail.com

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ABSTRACT

This study aims to analyze patterns of students' thinking interaction during group discussions in statistics learning and examine their impact on conceptual understanding, particularly across different levels of academic ability. A qualitative approach was employed using discourse and interaction analysis. Data were collected through classroom observations, video/audio recordings, transcription of student discussions, students' written work, and in-depth interviews. These instruments enabled comprehensive documentation and triangulation of students' verbal and behavioral interactions. Twelve junior high school students were selected and categorized into high, medium, and low academic ability groups. Discourse structures were analyzed using the Sinclair & Coulthard model (to identify classroom discourse moves) and Mercer's framework (to detect exploratory and cumulative talk). Furthermore, interaction patterns were categorized using the ICAP model—which distinguishes passive, active, constructive, and interactive engagement—and Bales' Interaction Process Analysis (IPA), which classifies social-emotional and task-related behaviors in small groups. The findings revealed that groups with explorative interaction patterns demonstrated deeper conceptual understanding, facilitated by active questioning, argument construction, and peer clarification. In contrast, static interaction groups were characterized by passive reception and rote learning, while counterproductive groups showed fragmented participation and communication breakdowns. These results confirm the vital role of interaction quality in supporting conceptual development. The novelty of this study lies in its integration of discourse- and interaction-based frameworks to reveal how different thinking dynamics shape learning outcomes in heterogeneous academic groups. Practically, the study highlights the importance of scaffolding, open-ended questioning, and structured facilitation to promote argumentation-rich discussions. These strategies are essential for fostering critical thinking and improving students' understanding of statistics concepts.

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A. INTRODUCTION

The interaction of students' thinking in group discussions plays a crucial role in learning mathematics, especially in understanding statistical concepts. Discussion allows students to express their thoughts, share ideas and build arguments that support their conceptual understanding (Chen et al., 2016; Torrens, 2021; Mercer, 2021). This is particularly relevant in the context of junior high school students, who often struggle with abstract statistical concepts such as data interpretation, central tendency, and variability. These topics require not only

procedural knowledge but also deep conceptual understanding, which can be fostered through peer interaction.

Discussion-based learning contributes to improving students' mathematical communication skills by giving them the opportunity to explain and defend their thinking (Fyfe et al., 2019; Kamid et al., 2020; Resnick et al., 2021). Through discussion, students not only convey answers, but are also asked to explain their thought process verbally, which can strengthen understanding and improve clarity in communicating mathematically. In addition, the interactions that occur during discussions also play a role in developing critical thinking skills, as students are encouraged to analyze their friends' arguments, evaluate various points of view, and formulate logical responses (Amobi, 2005; Littleton & Mercer, 2013). Focused and reflective discussions can also form deep thinking habits, help students recognize errors or misconceptions, and improve their understanding through mutual clarification. Thus, discussion is not only a medium for sharing ideas, but also a means to hone metacognitive skills and build stronger conceptual understanding.

Collaborative learning environments encourage students to share perspectives, discuss concepts, and clarify their understanding through structured dialog (Gillies, 2019; Kosko & Zimmerman, 2019; Lestari & Anggraini, 2022; Visser et al., 2023). In group discussions, students are encouraged to construct logical arguments, build analytical skills and develop effective problem-solving strategies (Minarti & Wahyudin, 2019; Slavin, 2008; Taar & Palojoki, 2021). However, not all group interactions lead to meaningful learning—some are passive, dominated by a few individuals, or lack critical engagement. This highlights the need to investigate the quality and nature of student interactions, rather than merely assuming discussion is effective.

Effective discussions allow students to develop deeper understanding through the exchange of ideas and constructive argumentation (Hennessy et al., 2021; Karousiou et al., 2022; Kosko & Zimmerman, 2019; Syarifudin et al., 2019). When students are active in discussions, they get the opportunity to they have learned to a broader context (Albano et al., 2022; Moran & Carroll, 2020; Sarimsakov et al., 2020; Tulviste, 2019). In addition, engagement in discussions also strengthens students' confidence in expressing opinions and improves higher-order thinking skills (Aulia et al., 2021; Donnelly & Fitzmaurice, 2011; Sudarwo & Adiansha, 2022; Tohidian & Nodooshan, 2021). Yet, research that specifically explores how patterns of thinking interaction emerge and how they relate to conceptual understanding in the domain of statistics particularly among students with varying academic abilities is still limited.

However, the effectiveness of group discussions is greatly influenced by the pattern of student interaction within them, as shown by the research of Bishop (2012) and Dejarnette & González (2016). For example, a study by Gätje & Jurkowski (2021) found that groups that had open communication and mutual support showed a significant increase in concept understanding compared to less interactive groups. In addition, a study by Memiş & Akkaş (2020) revealed that groups that implemented a critical argumentation-based discussion strategy were more successful in understanding statistical concepts than groups that only relied on passive task sharing.

These findings emphasize the importance of building productive interactions in group discussions to maximize learning effectiveness Syarifudin et al. (2019). In some groups,

thinking interactions are productive, with each group member actively contributing to building shared understanding Syarifudin; et al. (2018). Conversely, there are also groups that experience difficulties in communicating, which hinders the creation of a deep understanding of the concepts learned (Freeman et al., 2020). Therefore, the role of the teacher in guiding and directing the course of the discussion is a very important aspect in creating effective interactions (Gillies, 2019; Syarifudin et al., 2019).

Differences in the academic ability levels of students in a group also contribute to the interaction patterns that occur (Campbell et al., 2022; González & DeJarnette, 2015). Groups with a balanced academic composition tend to show more dynamic interactions compared to groups with significant academic differences (Zheng & Warschauer, 2015). In some cases, students with higher academic ability tend to dominate discussions, while other students become passive and participate less (Resnick et al., 2021). Therefore, understanding how academic ability levels affect students' interaction patterns is important in designing effective discussion groups (Çebi & Güyer, 2020; Zheng & Warschauer, 2015).

Previous research has shown that exploratory thinking interactions can improve conceptual understanding compared to interactions that only focus on receiving information without further discussion (Gillies, 2019; Mavrikis et al., 2022). In exploratory interactions, students are invited to question ideas, provide justification for their thoughts, and criticize the opinions of their peers (Alexander, 2008; Roden et al., 2020). This encourages deeper thinking and builds a more solid understanding of statistical concepts (Phan, 2011; Resnick et al., 2021). However, little is known about how such exploratory interactions manifest in real classroom settings and how they vary depending on students' academic levels. This gap leaves teachers without clear guidelines on how to structure group compositions and scaffold student dialogue effectively.

Therefore, encouraging explorative interactions in group discussions is one of the main strategies in improving the effectiveness of statistics learning (Roden et al., 2020). This study addresses the identified gap by analyzing the thinking interaction patterns of junior high school students during group discussions in statistics learning. Specifically, it examines how these patterns differ across academic ability levels and how they relate to students' conceptual understanding. By combining discourse and interactional analysis frameworks (Sinclair & Coulthard, Mercer, ICAP, and Bales IPA), this research offers a comprehensive approach to understanding the nature and impact of student discussions. The results are expected to inform instructional strategies that promote deeper student engagement and conceptual mastery.

B. METHODS

1. Research Design

This study used a qualitative approach with discourse and interaction analysis methods. Discourse analysis (Sinclair & Coulthard) was used to identify initiation-response-feedback patterns in discussions, while Mercer's framework distinguishes between cumulative, disputation, and exploratory talk to assess the depth of talk. The ICAP (Interactive, Constructive, Active, Passive) model is used to measure the level of cognitive engagement, and Bales' Interaction Process Analysis (IPA) to map socio-emotional behaviors and tasks in the group.

The combination of these four models is relevant for statistics learning, where conceptual understanding emerges through verbal interaction and shared reflection.

2. Participants

A total of 12 junior high school students were purposively selected and grouped according to academic ability (high, medium, low), based on cumulative math scores and teacher recommendations. Each group (n = 4) was balanced in terms of gender and communication style to avoid domination, so that each member had an equal opportunity to contribute.

3. Instruments

a. Classroom Observation & Recording: The observation guide included categories of verbal participation, turn-taking, questioning, and quality of explanation. Once developed, the guide was expert-validated and pilot-tested.
b. Discussion Transcription: Video/audio recordings were fully transcribed. Discourse analysis was then coded according to Sinclair & Coulthard and Mercer.
c. Written Document Analysis: A collection of students' written answers were analyzed to see how they formulated concepts individually.
d. In-depth Interview: Conducted post-discussion to clarify students' intentions and perceptions.

4. Procedures & Timeline

a. Pre-Observation (Week 1): Observing the classroom culture and refining the instrument.
b. Primary Collection (Weeks 2-4): Recording 3 discussion sessions (45-60 minutes per session) during a regular statistics lesson, then collecting written responses.
c. Reinforcement Interviews (Week 5): Each student was interviewed (~15 minutes) to explore their motives and reflections.

5. Validity & Reliability

a. Triangulation: Combining observation data, transcripts, written documents, and interviews.
b. Inter-Rater Reliability: Two independent raters coded the same segment of data; agreement was measured by Cohen's Kappa (target > 0.75). Discrepancies were discussed until consensus was reached.

6. Grouping Rationale

Academic ability groups were determined based on the distribution of math scores and teacher recommendations, and verified that each group had a variety of backgrounds (gender, speaking styles). This balancing ensures fair representation and supports the validity of comparing inter-group interaction patterns.

C. RESULT AND DISCUSSION

1. Patterns of Thinking Interaction in Group Discussion

Based on discourse and interaction analysis, three distinct patterns of student thinking interaction—exploratory, static, and counterproductive—were identified and examined for their impact on understanding statistical concepts. In the exploratory pattern, students actively posed critical questions, built on one another's ideas, and engaged in reflective argumentation, leading to deeper conceptual grasp. The static pattern was characterized by passive exchanges and minimal elaboration, resulting in surface-level comprehension. In contrast, the counterproductive pattern featured fragmented communication and uneven participation, which hindered the collaborative construction of knowledge. Subsequent sections illustrate how these patterns emerged within high-, medium-, and low-ability groups.

a. High Ability Group (K.TTT)

Groups with high academic ability showed more productive interaction patterns in group discussions. Students in these groups actively exchange ideas, provide critical responses to their peers' opinions, and build more structured arguments. The discussion process in these groups does not only focus on passively receiving information, but also involves in-depth elaboration and strong conceptual justification of the material discussed (Heron et al., 2023; Syarifudin et al., 2019). They tend to adopt exploratory communication patterns, where each group member actively questions, clarifies and develops ideas before reaching a common agreement (Kajzer-Wietrzny & Grabowski, 2021; Ronfeldt & Arquilla, 2020). The interactions that occur in these groups exhibit a reflective thinking cycle, where students not only express their opinions, but also revisit their arguments based on different points of view. Discussions that take place in this way allow students to deepen their understanding of the concepts learned and hone their critical thinking skills. In addition, the dynamics of challenging and questioning each other in the high-ability group discussions also helped to improve students' argumentative skills, which contributed to strengthening their understanding of concepts more comprehensively. In contrast to other groups who may be more inclined to follow the flow of the discussion without raising many critical questions or responses, the high-ability group was more active in building constructive discourse. Thus, this pattern of interaction within the group not only impacted on individual understanding, but also encouraged the formation of a richer and deeper collective understanding.

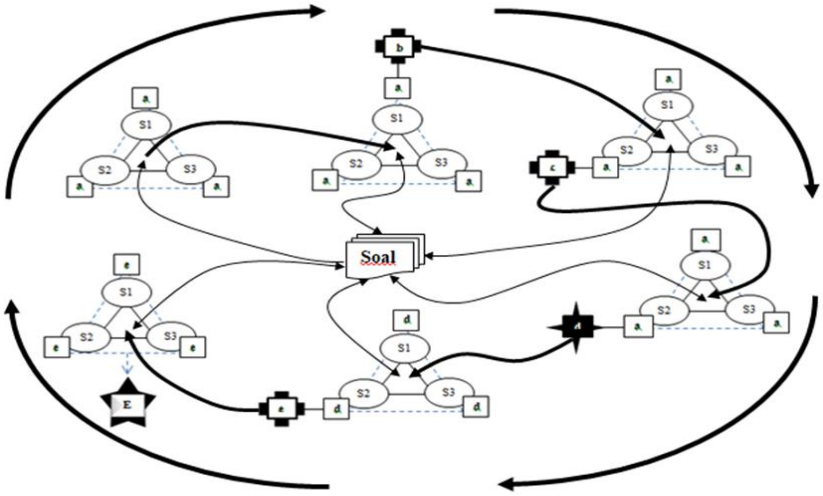

Figure 1. Idea Exchange in High Ability Group

The diagram of the exchange of ideas in the high-ability group, as shown in Figure 1, shows intensive interaction among students. This interaction reflects their active involvement in building deep conceptual understanding. Students in this group not only expressed their opinions, but also demonstrated the ability to listen actively, provide relevant responses, and connect new information with their previously acquired knowledge. This process is in line with Vygotsky (1978) theory of the zone of proximal development, which emphasizes that learning is more effective when social interactions occur that allow students to construct their understanding through discussions with peers. Recent studies have also shown that collaborative interaction in groups can improve students' understanding of complex concepts, especially in mathematics learning (Connor et al., 2009; Shehab & Mercier, 2020). Students in high-ability groups tend to use reflective thinking strategies, question each other's arguments, and provide logical justifications for their opinions. In addition, the discussions conducted in these groups involve more concept elaboration, which allows students to explore ideas in more depth and build a more holistic understanding (Çebi & Güyer, 2020; Li & Yang, 2021).

b. Medium Ability Group (K.SSS)

The medium ability group showed a static pattern of interaction with an uneven level of participation among group members. In discussions, only one or two individuals play a more dominant role in expressing opinions, while other members act more as passive listeners who receive information without further exploration. This phenomenon is in line with the findings of Syarifudin et al. (2019) who stated that in groups with low interaction dynamics, students tend to follow the majority opinion without any challenge or in-depth discussion that can trigger critical thinking. The lack of encouragement to elaborate ideas in these groups may limit students' opportunities to develop deeper conceptual understanding (Kinchin et al., 2000). In addition, recent research shows that groups with unbalanced interaction patterns have a tendency to experience difficulties in linking the concepts being learned with their prior knowledge (Le et al., 2018). Although some students in these groups are able to respond to ideas

presented, their responses are often superficial and not oriented towards collaborative problem solving. Therefore, the lack of exploration of ideas in the discussions of the medium-ability group may hinder the development of their critical thinking skills and conceptual understanding of the material studied. To improve the effectiveness of learning in these groups, intervention strategies such as scaffolding are needed that can help encourage students' active involvement in discussions (Anghileri, 2006; Kim, 2020).

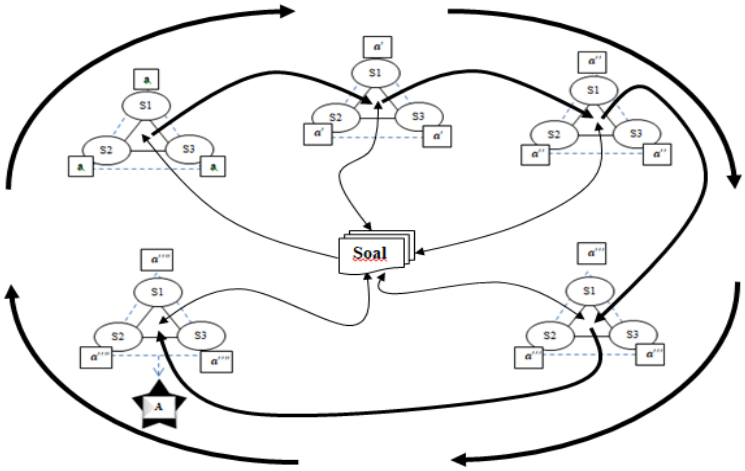

Figure 2. Idea Exchange in Medium Ability Group (K.SSS)

Figure 2 shows a graph of interaction in a medium-ability group, which illustrates an uneven communication pattern among group members. Although there is interaction between members, not all students actively participate in the discussion. Some individuals tend to dominate the conversation, while others are just passive listeners or provide minimal responses to the exchange of ideas that occur. This phenomenon is in accordance with the findings of Syarifudin et al. (2019), who emphasized that the effectiveness of group work in learning is highly dependent on the level of involvement of all members, not just the contribution of a handful of students. This imbalance in interaction can cause some students to miss the opportunity to develop deeper conceptual understanding due to a lack of involvement in the collaborative thinking process (Pierce & Gilles, 2021). In addition, recent research by Albano et al. (2022) shows that in groups with an unbalanced communication pattern, the process of negotiating meaning and exploring concepts is limited, thus hindering the development of students' critical thinking skills. Another factor contributing to low participation is the lack of discussion facilitation strategies that can encourage the active involvement of all group members. van de Pol et al. (2010) highlight the importance of using scaffolding and prompting techniques to stimulate students to be more active in discussions. Therefore, in the context of discussion-based learning, a more systematic approach is needed to ensure that all students have equal opportunities to exchange ideas and build understanding collaboratively. By implementing more inclusive strategies, interactions in groups can be more dynamic and provide maximum benefits for all students involved.

c. Low Ability Group (L.RRR)

Low ability groups show the most counterproductive interaction patterns in group discussions. The dominance of certain individuals in this group often causes other members to be passive or even not participate at all. This situation reflects the findings of Russell & Jarvis (2019), who stated that in groups with large ability gaps, students with lower understanding tend to withdraw from discussions because they feel less confident or are afraid of giving the wrong answer. Recent research by Gillies (2019) also shows that in groups with dynamics like this, students' opportunities to develop critical and reflective thinking skills are very limited. Students with low abilities tend to adopt the role of recipients of information rather than active participants in the discussion, which ultimately hinders the development of their understanding of the concepts discussed (Barab & Plucker, 2002). In addition, low intrinsic motivation and minimal scaffolding strategies from peers or facilitators also worsen the quality of interactions in this group (Joannidis et al., 2020). In fact, previous research has emphasized that the success of discussion-based learning is highly dependent on the active involvement of all group members (Wilson et al., 2007).

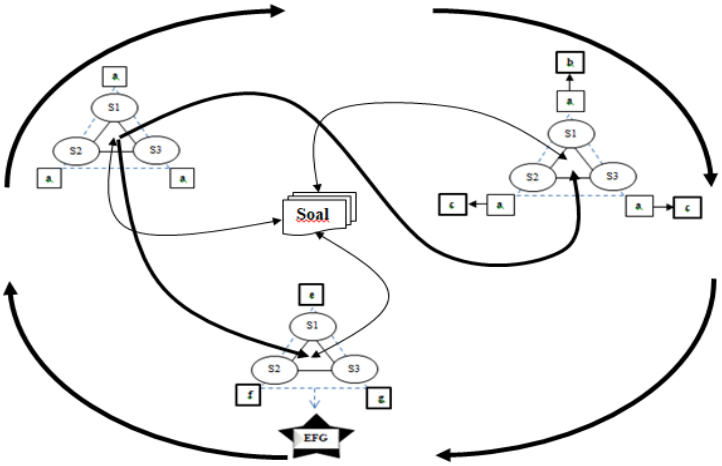

Figure 3. Exchange of Ideas in Low Ability Groups (K. RRR)

Communication patterns in low-ability groups, as shown in Figure 3, are generally one-way with minimal responses and challenges to the ideas put forward. The lack of exploratory interaction in this group has the potential to hinder students' understanding of the concepts being studied, as stated by Almås et al. (2023), who emphasized that discussions that do not involve elaboration of ideas and conceptual justification tend to be ineffective in improving students' understanding. In this context, teacher intervention becomes very important to create a more dynamic discussion environment. Vygotsky (1978) emphasized that scaffolding, or gradual support from educators, can help students build deeper understanding by providing guidance that is appropriate to their developmental level. A recent study by Wang et al. (2022) also showed that providing scaffolding in group discussions can increase student engagement and encourage them to be more active in conveying and defending their arguments. In addition, the use of open-ended question-based learning strategies and constructive feedback can help students develop reflective and critical thinking Gillies (2019). Thus,

teachers need to actively observe the discussion, provide thought-provoking questions, and encourage students to respond to each other's ideas. Through this approach, it is hoped that interactions within groups can be more oriented towards in-depth conceptual exploration, thereby supporting increased student understanding of the material being studied.

2. The Relationship between Thinking Interaction and Conceptual Understanding

Thinking interactions in group discussions play a very important role in shaping students' conceptual understanding. Various studies have confirmed that interaction patterns in groups can determine the extent to which students understand the material being studied (González & DeJarnette, 2015; Schroedler, 2021). Discussions that are carried out actively and exploratively allow students to construct their understanding through an in-depth exchange of ideas. Conversely, groups that have passive or counterproductive interaction patterns tend to have difficulty understanding the concepts being taught. In this study, it was found that groups with exploratory interactions showed better understanding compared to groups that only had limited interactions. This shows that the quality of interaction in group discussions greatly determines the effectiveness of the learning that takes place. Therefore, in the discussion-based learning process, it is important for teachers to create an environment that supports more active and collaborative interactions. This approach not only improves students' understanding but also encourages them to think more critically and reflectively about the material being studied. In addition, the effectiveness of group discussions can be increased through learning strategies that emphasize open-ended questions and providing constructive feedback (Gillies, 2019). Thus, students' understanding can develop more optimally through social interactions that are rich in the exchange of ideas and in-depth arguments.

Groups that implement exploratory interactions tend to have a stronger understanding of concepts because they are active in asking questions, clarifying, and providing reasons for the answers put forward. In exploratory discussions, students are encouraged to think more deeply and connect concepts they have previously learned with the material being discussed. This approach is in line with the theory of the Zone of Proximal Development (ZPD) proposed by Vygotsky (1978), which states that a person's understanding develops through social interactions that allow for support from other individuals who are more experienced. In the context of group discussions, this support can be in the form of elaboration of thoughts from peers who have better understanding or teachers who act as facilitators. A study conducted by Roden et al. (2020) also showed that exploratory interactions in group discussions can improve students' understanding of mathematics and science concepts more significantly compared to learning methods that are only centered on teachers. In addition, exploration-based discussions allow students to develop critical thinking skills, namely the ability to analyze a concept from various perspectives before reaching a more comprehensive conclusion. Therefore, in group-based learning, it is important to encourage communication patterns that emphasize elaboration and argumentation, so that students can gain a deeper understanding of the concepts being learned.

In contrast, groups with static interactions tend to focus more on repeating information without further exploration. Students in this group memorize concepts more mechanically

without understanding how the concepts are applied in various situations. As a result, they have difficulty when they have to apply the concepts learned to solving real problems. Plebe & Grasso (2019) emphasized that students who only receive information passively without discussing or testing it in various contexts will have a shallow understanding and are more susceptible to misconceptions. In addition, minimal interaction in groups can hinder the development of students' critical thinking skills because they are not used to asking questions, analyzing arguments, or developing alternative points of view. In this condition, the role of the teacher becomes very important in directing the discussion to be more active and reflective. One strategy that can be applied is to provide guiding questions that can stimulate students' thinking and encourage them to explore concepts in more depth (Gillies, 2019). Thus, this approach can help students who tend to be passive to be more active in discussions and improve their conceptual understanding through more meaningful interactions.

Meanwhile, groups with counterproductive interactions have difficulty solving statistical problems due to a lack of collaboration and effective communication. In these groups, students tend to work individually or only follow the direction of one dominant individual without any in-depth discussion. This phenomenon often occurs in groups that have a high ability gap, where students with lower understanding feel less confident or afraid of giving the wrong answer (Cohen-Tannoudji et al., 2022; Siegle, 2022). As a result, the discussion process becomes unbalanced because only a small number of group members are really involved in the thinking and decision-making process. This has an impact on students' low understanding of the concepts being studied, because they do not get the opportunity to actively develop ideas. To overcome this problem, a learning strategy is needed that can increase the participation of all group members evenly. One approach that can be used is cooperative learning with a clear division of roles, so that each student has a responsibility in the discussion process (Hedeen, 2003). In addition, providing positive feedback and motivation from teachers can also help increase the self-confidence of students who are less active. By implementing this strategy, it is hoped that interactions within the group can be more balanced and constructive, thus supporting students' understanding of the concepts being studied.

The impact of interaction patterns in group discussions is also supported by the findings of Dillenbourg (2007), who emphasized that the effectiveness of group work is highly dependent on how actively students participate and share their thoughts. If the discussion is dominated by only one or two individuals, then other students will experience limitations in developing their understanding. Therefore, teachers have a crucial role in managing the dynamics of the discussion so that all students have an equal opportunity to participate. One strategy that can be applied is the scaffolding approach, namely providing gradual support to students so that they are more confident in expressing ideas and contributing to the discussion (Vygotsky, 1978). A recent study conducted by Henning (2007) shows that the use of scaffolding in discussion-based learning can increase student engagement and help them develop a deeper understanding of the concepts being taught. In addition, the use of question-and-answer-based learning strategies, guided discussions, and more structured group work can also improve the quality of interactions in group discussions (Gillies, 2019). By adopting a more systematic approach to managing discussions, teachers can create a more inclusive learning environment

and encourage each student to be active in building their understanding both independently and through interactions with their peers.

D. CONCLUSION AND SUGGESTIONS

This study unequivocally confirms that explorative interaction patterns in group discussions, where students ask each other critical questions, provide justifications, and jointly construct arguments are directly related to the research objective of assessing the influence of interaction patterns on statistical concept understanding. The core findings showed that groups with exploratory interactions achieved deeper conceptual understanding than groups with static patterns, which tended to be passive and only repeated information, as well as counter-productive groups, where communication was fragmented and participation was uneven. Practically, these results emphasize the important role of educators and curriculum developers in designing learning environments that facilitate the exploration of ideas. Teachers should use scaffolding strategies based on open-ended questions and division of discussion roles. For example, questioners, explainers and note-takers and set turn-taking norms to ensure all students actively contribute. At the curriculum level, it is recommended to integrate structured discussion modules that emphasize the stages of exploration and reflection, so that positive social dynamics are built and students are encouraged to think critically. For recommendations, focus on two key aspects. First, the management of social dynamics: training teachers in role-sharing techniques and discussion rules can balance participation, minimize dominance, and encourage more exploratory interactions. Second, the integration of collaborative technologies: the use of digital platforms such as discussion forums on a Learning Management System allows for pre-discussion and written reflection, extending the exploration of ideas beyond the classroom and providing a track record of interactions that can be analyzed for ongoing feedback.

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