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The dynamics of behavioral pattern in collaborative problem-solving among Indonesian preservice mathematics teachers

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Abstract

The research examines the behavioral dynamics of Indonesian preservice mathematics teachers and identifies the types of scaffolding they require to enhance their participation in collaborative settings. A key novelty of this research is the application of the Net Promoter Score as a classification framework for grouping preservice teachers in educational research. Using this NPS-based categorization, combined with mathematical problem-solving performance, we conducted a qualitative study involving two underperforming subjects: promoters and passives. The analysis reveals distinct behavioral transition patterns: the promoters group repeatedly shifted actions across different problem-solving steps, while the passives group repeated actions within a single step. Despite these differences, both groups displayed similar needs for scaffolding, i.e. in interpreting actions and coordinating communication. Notably, the promoters group progressed through all four problem-solving steps, whereas the passives group did not reach the final stage. These findings contribute to a deeper understanding of collaborative roles in group-based mathematical problem-solving and highlight the potential of tailored scaffolding to support preservice teachers' engagement in collaborative mathematical work.

Keywords:
Behavioral pattern, Collaborative problem solving, NPS, Preservice mathematics teacher, Teacher training

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1. INTRODUCTION

Collaborative problem-solving (CPS) has emerged as a critical competency for preservice teachers (PTs). CPS integrates both cognitive and social processes required to collaboratively make sense of mathematical tasks, coordinate actions, negotiate meaning, and construct shared solutions (Graesser et al., 2017; OECD, 2017; Roschelle & Teasley, 1995). As a professional skill, CPS supports PTs in connecting pedagogical knowledge with mathematical content and communication practices, thereby strengthening essential components of teacher professional competence. Research has also shown that CPS fosters higher order thinking skills, particularly critical thinking, because collaboration requires individuals to articulate arguments, justify strategies, consider alternative viewpoints, and coordinate reasoning to reach consensus (Barron, 2000; Gillies, 2016). Through these dialogic and reasoning-oriented interactions, PTs develop deeper conceptual understanding, improved metacognitive regulation, and increased confidence in navigating instructional problems. Given these pedagogical and cognitive affordances, it is crucial to understand how PTs engage with CPS tasks and how their behaviors evolve during collaboration.

The success of collaboration and problem-solving is shaped by the interplay of participants' prior knowledge, problem-solving competence, motivation, emotions, and interpersonal skills (Järvenoja & Järvelä, 2010; Morgeson et al., 2005; O'Neill et al., 2012). The CPS literature distinguishes two main dimensions: the cognitive dimension, which encompasses strategic reasoning, analysis, and planning; and the social dimension, which involves communication, negotiation, coordination, and socio-emotional regulation (Fiore et al., 2017; Hesse et al., 2015; OECD, 2017). Both dimensions are essential for productive collaboration, and both influence how PTs interpret problems, share ideas, and adjust their actions during teamwork.

An individual's characteristics such as attitudes toward collaboration also play an important role in mathematical problem-solving. Tools, such as the Net Promoter Score (NPS) offer insight into participants' willingness to support peers, engage actively, and contribute to collaborative problem-solving tasks. Furthermore, in the classroom setting, the collaborative processes are further shaped by scaffolding, defined as structured support that helps learners progress beyond what they can achieve independently (Anghileri, 2006; Wood et al., 1976). Scaffolding is especially influential in CPS contexts because it guides learners in coordinating actions, interpreting peers' contributions, and sustaining shared focus on mathematical goals.

Despite the growing body of international CPS research (Felmer, 2023; Renninger et al., 2025; Watson & Chick, 2001), there remains limited empirical work focusing on the CPS performance of PTs in Indonesia. Previous Indonesian research has shown mixed evidence regarding the effectiveness of collaboration such as Retnowati et al.'s (2017) findings that collaboration benefits students only under problem-solving conditions but may be counterproductive with worked examples, and Wawan et al.'s (2023) evidence that project-based, culturally integrated models can enhance collaboration alongside other competencies, indicating that the role of collaboration in mathematics learning is still not fully understood. However, these studies do not examine the CPS performance of PTs. Thus, doing the work focusing on the CPS performance of PTs in Indonesia is significant for several reasons. First, Indonesian PTs typically experience mathematics instruction that is more procedural and teacher-centered (Wijaya et al., 2018) which may influence how they collaborate, reason, and communicate in group problem-solving contexts. Second, Indonesian PTs must navigate diverse classroom environments characterized by cultural norms that emphasize harmony and deference, potentially affecting participation dynamics during collaborative work.

Understanding how Indonesian PTs engage in CPS therefore provides valuable insight for the international community by illustrating how cultural, pedagogical, and institutional contexts shape collaborative behaviors. Furthermore, no existing research has examined how underperforming PTs behave during CPS tasks, how their engagement differs based on collaborative attitudes categorized by the NPS (e.g., promoters vs. passives), and what forms of scaffolding they require.

The 2015 Programme for International Student Assessment (PISA) included a CPS assessment to measure students' proficiency in 12 specific CPS skills, each conceptualized as observable actions or responses. The PISA framework identifies four problem-solving steps (exploring and understanding, representing and formulating, planning and executing, and monitoring and reflecting), three competencies (establishing and maintaining shared understanding, taking appropriate action to solve the problem, and establishing and maintaining group organization), and 12 corresponding behavioral components formed at their intersections. These components structure the cognitive and social expectations of collaborative tasks across domains such as mathematics, science, reading, and broader societal issues (OECD, 2017). Because this study examines preservice mathematics teachers working on mathematical problem-solving tasks, this framework offers an appropriate and contextually aligned basis for the research.

Scaffolding, grounded in Vygotsky's Zone of Proximal Development (ZPD), refers to temporary support that enables learners to accomplish tasks they cannot yet perform independently. As competence grows, this support is gradually withdrawn. Effective scaffolding must be both appropriate and timely (Walqui, 2006). Assistance that is excessive or mistimed may inhibit learning, while well-calibrated guidance helps learners progressively develop autonomy. Anghileri (2006) further characterizes scaffolding into three levels, each comprising specific instructional actions that guide learners' cognitive and collaborative development. In CPS contexts, scaffolding is especially crucial because learners must simultaneously manage cognitive demands and coordinate socially with peers (Hmelo-Silver, 2004; Reiser, 2004). Effective scaffolding helps PTs articulate their reasoning, attend to peers' ideas, and maintain shared focus, behaviors that align directly with the 12 CPS skills defined in the PISA framework. Moreover, prior research has shown that well-structured scaffolding can enhance collaborative engagement and support learners in transitioning from peripheral to more active participation during group work (van de Pol et al., 2010; Webb et al., 2014). Building on these insights, examining scaffolding within PTs' CPS behaviors becomes essential for understanding how support can be tailored to learners with differing levels of collaborative engagement.

To address the gaps identified above and provide valuable insights into this domain, this study aims to examine the behavioral transition patterns among Indonesian PTs in CPS tasks, focusing on the 12 CPS skills in the PISA 2015 framework as observable "behaviors". Particular attention is given to PTs who underperform in mathematical problem solving, as they often require additional instructional support. These PTs are categorized into promoters and passives based on the NPS, enabling analysis of how differing levels of engagement shape collaborative dynamics. Promoters are more likely to assist and encourage their peers, while passives tend to show low initiative and limited responsiveness. Investigating these roles allows for a nuanced understanding of how cognitive and social dimensions of CPS manifest in real-time behavior and reveals the types of scaffolding that can enhance PTs' collaborative learning.

2. METHOD

2.1. Research Design

This study employed a qualitative approach to examine the behavioral transition patterns of PTs during CPS tasks and to identify the types of scaffolding they required. The analysis focused on two purposefully selected cases representing distinct profiles of CPS engagement: (1) PTs with deficient mathematical problem-solving performance who were classified as promoters, and (2) PTs with the same deficient proficiency but classified as passives.

2.2. Participants and Procedures

Participants were Indonesian PTs enrolled in the sixth semester of a four-year undergraduate mathematics education program. All PTs had completed coursework in mathematics, pedagogy, classroom communication, and microteaching preparation. They have the same academic background, i.e., had passed calculus, geometry, algebra, problem-solving, and pedagogy courses. A two-stage strategy of participants selection was used:

Stage 1: A total of 58 PTs completed the CPS experience questionnaire, which captured their attitudes and collaborative behaviors using the NPS framework. From these, 21 PTs were purposively selected, representing the broader sample, to engage in a mathematical problem-solving test.

Stage 2: Case selection. Only PTs who met the following criteria were eligible for case study sampling: Classified as deficient in mathematical problem solving and classified as promoters or passives in CPS experience.

From those steps, two representative groups were selected: Group 1 (Promoters - consisting of 3 PTs) and Group 2 (Passives - consisting of 3 PTs). The selection was intentional, allowing for in-depth comparisons between two contrasting CPS behavioral profiles. These two groups served as the analytic units, not as representative samples of the entire population.

2.3. Instruments

CPS Experience Questionnaire

The instrument of CPS experience questionnaire consists of 20 items that cover key aspects, including communication, contribution, coordination, and problem-solving engagement. Each aspect is represented by 5 statements, and participants are required to assign their choice representing a score from 0 to 10, with a bigger score representing a more positive attitude towards the CPS experience. A score of 0 does not indicate "absence of CPS ability", but rather "absence of observable positive behavioral indicators" in that construct (similar scaling is used in satisfaction and experience instruments, e.g., Lam & Tong, 2023). Since the measure captures attitudes and experiences, not CPS performance, thus 0 is conceptually valid.

Their total scores are averaged. Participants are classified as detractors if the average score (AS) falls from $0 \leq AS < 7$. An average score of $7 \leq AS < 8$ places them in the passives category, while an average score of $8 \leq AS \leq 10$ identifies them as promoters. The attributes measured in the communication aspect involve the ability to communicate effectively with other team members. In the contribution aspect, the attribute measured is the level of participation in solving problems. The coordination aspect measures the ability to organize tasks and allocate work. Lastly, the problem-solving aspect assesses the ability to identify issues and find solutions. This instrument was adapted from various sources, including the online learning effectiveness questionnaire (Darius et al., 2021), the student satisfaction and performance questionnaire in online classes (Gopal et al., 2021), and the online learning process questionnaire (Lam & Tong, 2023). Before use, the instrument underwent expert review (content validity) and construct validation, in which preliminary testing was conducted with 32 PTs outside the research participants.

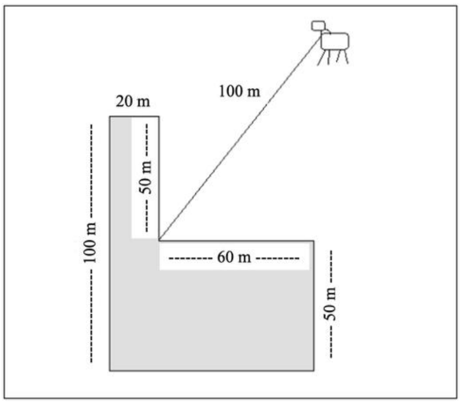
Mathematical Problem Solving Task

The following two problems were used to categorize PTs' problem-solving into three levels: deficient, medium, and high. Both problems were reviewed and validated by two experts in mathematics education to ensure their appropriateness and content accuracy. The analysis was conducted using time triangulation to strengthen the reliability of the findings.

The scoring rubric consisted of five descriptors: a score of 0 indicated no strategy, irrelevant work, or an absence of mathematical reasoning; a score of 1 reflected a minimal attempt with fragmented ideas and incorrect reasoning; a score of 2 represented the use of a partial strategy with some correct reasoning but major gaps; a score of 3 indicated an appropriate strategy with minor errors or incomplete execution; and a score of 4 signified a correct strategy supported by complete reasoning and an accurate solution. Based on these descriptors, participants' problem-solving was categorized into three levels as follows. For the purposes of this study, only PTs whose scores placed them in the deficient proficiency category were selected.

$0 \leq x \leq 1$: *deficient problem-solving*
$1 < x \leq 2$: *medium problem-solving*
$2 < x \leq 4$: *high problem-solving*

(1) *A goat is tethered to the corner of a pen with a 100-meter-long rope. The pen is an L-shaped structure with the dimensions (in meters) shown in the image. If the area outside the pen is open grassland that the goat can graze, how much of the grassland can the goat reach? (Source: math.stackexchange.com)*



(2) A conical glass contains a fixed amount of water. When the glass is placed upright, with its pointed end at the bottom, the water surface lies 2 cm below the rim. When the glass is inverted, the water surface is 8 cm above the vertex. Determine the height of the glass. (Source: gmatclub.com)

Both tasks encourage participants to explore different problem-solving strategies, employ visualization skills, and apply mathematical concepts in practical scenarios, making them suitable for measuring mathematical problem-solving.

CPS Online Assessment

The CPS online assessment employed the following problem, which was adapted from the Colearn website with several numerical modifications.

A 185 cm tall basketball player is practicing putting the ball in the hoop. He stands 5 meters away from the ring with a height of 3 meters. If the maximum height of his throw is 4.5 meters and the ball reaches its maximum height when it is 3 meters away from the player, then does the ball enter the ring?

Participants collaboratively solved a task requiring mathematical modeling using quadratic functions. The task required identifying known and unknown quantities, constructing relationships, modeling the ball's trajectory, and evaluating whether it reaches the hoop. The problem's interdisciplinary nature ensured a rich environment for CPS behaviors.

Coding Scheme

Each group participated in a collaborative problem-solving session conducted through an online meeting platform, during which they worked on the assigned CPS task for approximately 50 minutes. All sessions were fully recorded, including video, audio, and screen-sharing activities. The recordings were transcribed verbatim and subsequently coded to capture all group interactions, participant actions, and instances of instructor scaffolding.

Table 1. Matrix of collaborative problem-solving skills for PISA 2015

	(1) Establishing and Maintaining Shared Understanding	(2) Taking Appropriate Action to Solve the Problem	(3) Establishing and Maintaining Team Organization
(A) Exploring and understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve the problem
(B) Representing and formulating	(B1) Building a shared representation and negotiating the meaning of the problem (common ground)	(B2) Identifying and describing tasks to be completed	(B3) Describe roles and team organization (communication protocol/rules of engagement)
(C) Planning and executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement (e.g., prompting other team members to perform their tasks)
(D) Monitoring and reflecting	(D1) Monitoring and repairing shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback, and adapting team organization and roles

The coding was performed according to Table 1 (collaborative problem-solving skills) and Table 2 (scaffolding levels). For instance, when a group member inquired, "Is doodling necessary?" this question was categorized and designated as B2 (Identifying and describing tasks to be completed). When a group member demonstrated to her peers that she was revising the illustration made by another member, this behavior was classified as C1 (Communicating with team members about the actions to be/being performed). In the final example, when the instructor asked for the apex coordinate to ensure the ball could enter the hoop, this guidance was classified as S24 (Parallel modeling). Two coders independently coded all data, and any discrepancies in coding were resolved through discussion to ensure reliability.

Table 2. Level of scaffolding adapted from Anghileri (2006)

Level	Description	Code
1	Provide structured tasks	S11
	Facilitate peer collaboration	S12
2	*Reviewing*:	
	Pointing out student mistakes and providing opportunities to explain	S21
	Asking prompting and probing questions	S22
	Interpreting students' actions and talk	S23
	Providing parallel modelling	S24
	Getting students to explain and justify	S25
	Restructuring:	
	Identifying meaningful contexts	S26
	Simplifying the problem	S27
	Rephrasing students talk	S28

Level	Description	Code
3	Developing Representational Tools	S31
	Making Connections	S32
	Generating Conceptual Discourse	S33

3. RESULTS AND DISCUSSION

3.1. Results

There were 58 PTs who were given the NPS questionnaire and 21 subjects were selected purposively, 14 demonstrated deficient problem-solving performance, 5 showed moderate performance, and 4 exhibited high performance. Meanwhile, based on the CPS classification, 2 were identified as detractors, 10 as passives, and 9 as promoters. These participants were subsequently divided into six collaborative groups as presented in Table 3. Our analysis focuses specifically on Groups C and D, which we subsequently refer to as Group 1 and Group 2 for clarity.

Group Dynamics and Performance of Group 1 following to Figure 1 presents the CPS undertaken by Group 1 which demonstrates a complex process marked by the recurrent transition of particular activities. The dynamics of interaction within the group and between the group and the instructor reflect both internal and external efforts aimed at achieving the team's objective, i.e., arriving at a solution.

Table 3. PS and NPS results

Group	Students	PS	NPS
A	BN	High	Promoter
	WF	High	Promoter
	CC	Medium	Promoter
B	NA	High	Passive
	FA	High	Passive
	DZ	Medium	Passive
	SD	Medium	Passive
C	AS	Deficient	Promoter
	MM	Deficient	Promoter
	DB	Deficient	Promoter
D	KN	Deficient	Passive
	FN	Deficient	Passive
	RY	Deficient	Passive
E	AB	Deficient	Promoter
	NA	Deficient	Passive
	SW	Deficient	Detractor
	FF	Deficient	Detractor
F	PD	Deficient	Promoter
	MR	Deficient	Promoter
	NK	Deficient	Passive
	AY	Deficient	Passive

Collaborative problem-solving in Group 1 proceeded with the provision of level 1 scaffolding, namely facilitating peer collaboration (S1) by forming groups and inviting groups to start the discussion. One member who clearly understood their role initiated their collaboration by sharing a Jam board link to facilitate discussion (A3). Meanwhile, another member attempted to communicate the action being performed by presenting the problem (C1). She shared a sketch she had created. This initial phase underscores the significance of establishing a foundation for efficient teamwork when group members familiarize themselves with each other's roles and identify cooperative ways to tackle the task. Collaborative problem-solving in Group 1 concluded with one member executing the plan by identifying the apex or the highest point of the ball (C2). To guide Group 1 toward their conclusion, interpreting the group actions and talks was provided through a question regarding the implications of the obtained answer (S23). This prompted the other member to monitor the results of their actions, leading to the conclusion that the ball did not enter the hoop (D2).

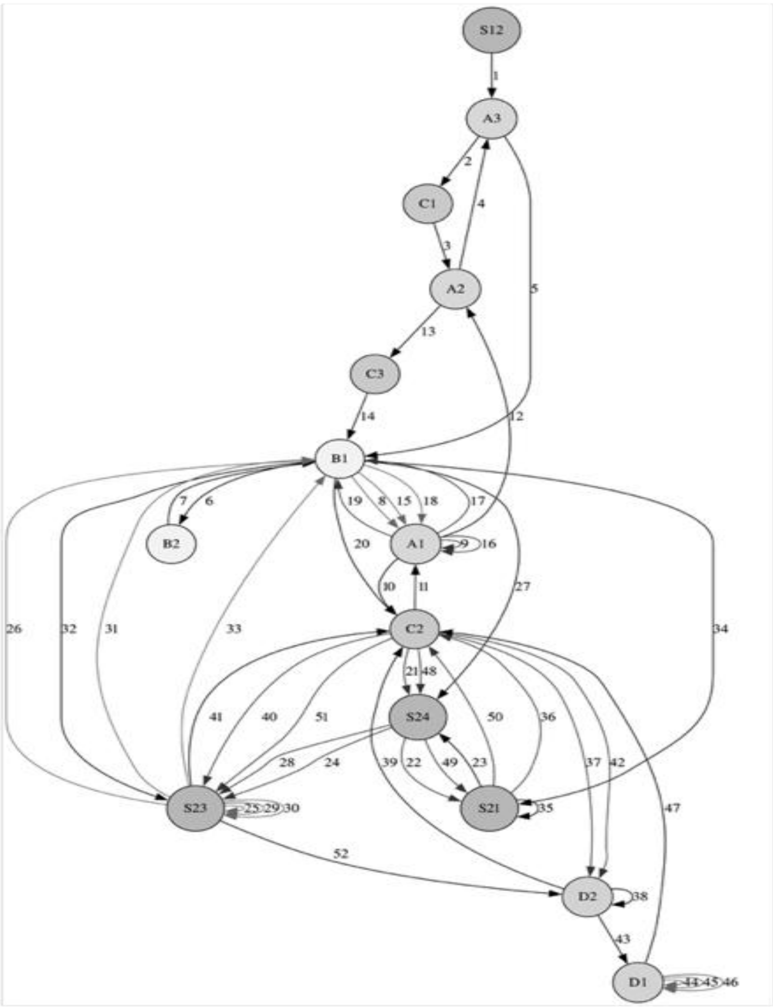


Figure 1. CPS dynamics of group 1

One significant recurring pattern involves moving from building a shared representation and negotiating the meaning of the problem (B1) to rediscovering the perspectives and abilities of team members (A1). This pattern manifests, for example, when one member clarified a statement previously made by a teammate about the path of a throw, questioning if it implies a parabolic trajectory. This is followed by another member attempting to interpret and write the general form of the parabolic equation. Another notable repetition is the shift from the instructor's interpretation of the group's actions and discussions (S23) to rebuilding a shared understanding and negotiating the problem's meaning (B1). An example is when the instructor referred to the axis of symmetry mentioned by a group member, questioning its implications for the x-axis intercepts, and suggested considering the midpoint between the first and second intercepts. This clue prompted one group member to interpret the distances as equal, concluding that half the distance between the first and second x-axis intercepts is 6 meters.

The final recurring pattern involves repeated cycles of monitoring and adjusting results (D1) after executing their plans. Group members took turns in this process: one asked about determining the point (0,0), followed by another explaining that it represents the moment the basketball player is about to throw the ball. Another member then clarified whether the peak point should be considered, prompting the group to reconsider related situations. The repetitions above underscore three key points: (1) the group's challenge in fully aligning perspectives and achieving a shared understanding among all members, (2) the pivotal role of the instructor's guidance in directing the group toward a deeper, more accurate grasp of the problem, and (3) the group's active self-regulation as they monitor their progress and make adjustments as needed.

The level 1 and 2 scaffolding provided by the instructor played an essential role in the progress of CPS in group 1, especially when they faced challenges and required repeated negotiation and alignment. Facilitate peer collaboration (S12) was provided to encourage them to start collaboration. As the problem-solving process progressed, level 2 scaffolding became increasingly necessary. It appears in the form of pointing out mistakes and providing opportunities to explain (S21), interpreting actions and talk (S23), and parallel modelling (S24). Interpreting students' actions and discussions (S23) emerged as the most vital form of scaffolding. It was often followed by efforts to rebuild a shared representation and renegotiate the problem's meaning or reenact their plans.

Group Dynamics and Performance of Group 2 following to Figure 2 illustrates the collaborative problem-solving (CPS) process undertaken by Group 2, revealing a more complex dynamic. The group engaged in more frequent communication, accompanied by plenty of scaffolding, which underscores its importance in facilitating the CPS process within Group 2.

In Group 2, collaborative problem-solving began with level 1 scaffolding, i.e., facilitated peer collaboration (S12) by organizing the groups and prompting them to start their discussion. After receiving the scaffolding, the group immediately engaged in the CPS process, as indicated by one member understanding her role (A3). She facilitated the discussion by presenting the problem so all members could see it. Another member responded to this action, confirming what she was doing, which shows that she communicated with the team about the action being taken (C1). Once this initial action was sufficiently clear to the team, another team member started to get into the problem. She led the team to identify the problem by asking questions about the nature of the problem (B2).

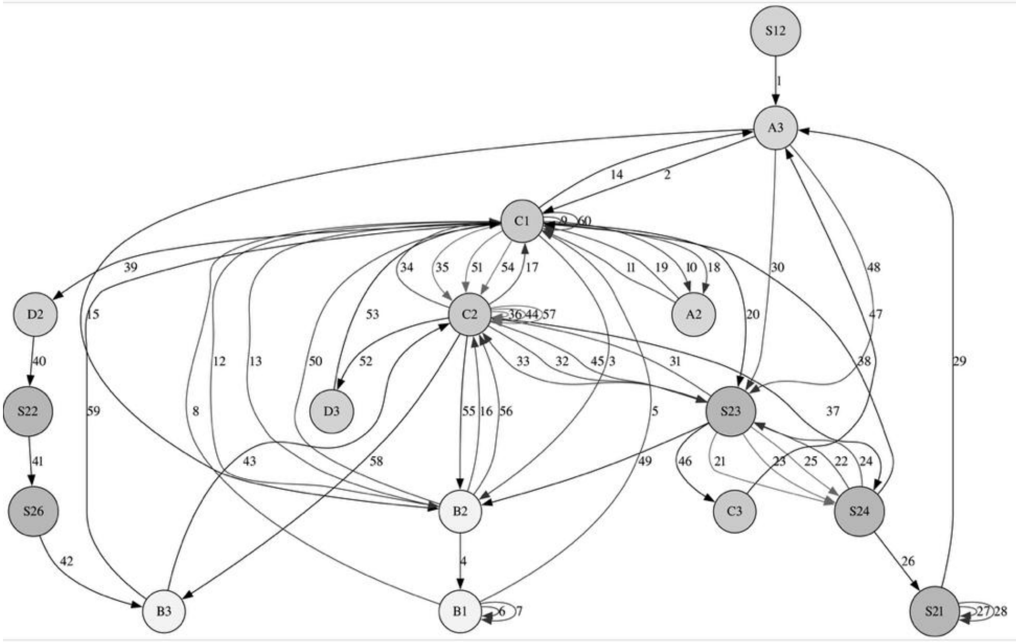


Figure 2. CPS dynamics of group 2

Group 2's CPS concluded with one member describing roles and team organization (B3). She divided the roles of the group members to solve the problem by utilizing technology. This action was followed by the recurring activity of communicating the actions being performed (C1). They continued to discuss the problem illustration, which concluded the CPS in Group 2.

One noticeable recurring pattern is the movement from interpreting the group's actions and talk (S23) to parallel modeling (S24). Among the conversations that show this movement is the instructor's role in emphasizing what group members had mentioned by asking about the conditions that must be met if the ball enters the ring. This question was followed by supportive prompts encouraging the group to view the known values as components in the formula and confirming whether the ball's height of 4.5 meters and the 3-meter distance between the hoop and the thrower would enter the hoop. Another frequent shift is from team communication about ongoing actions (C1) to enacting plans (C2). An example is a member informing a teammate that she was recalling the formula for determining a quadratic equation through three points, followed by another member applying this formula to find the answer. Additionally, repeated enactment of plans (C2) frequently appeared as group members completed or expanded upon solutions provided by their peers.

The repetitions above underscore three key points: (1) The instructor's pivotal role in stimulating the group's critical thinking about the problem's requirements and constraints, which clarifies the task and fosters a structured modeling approach by breaking down complex conditions into manageable parts, (2) Effective communication acts as a catalyst for collaborative action, facilitating a seamless flow from planning to execution, and (3) Group members not only engage in their roles but also actively build on one another's ideas, creating a more cohesive and dynamic solution process. Level 1 notably facilitating peer collaboration (S12), and level 2 scaffoldings supported the progress of Group 2 from the beginning of their collaboration to reaching a solution. Five types of level 2 scaffolding were crucial, providing critical assistance when the group faced challenges. It came in the form of pointing out mistakes and providing opportunities to explain (S21), prompting and probing questions (S22), interpreting actions and talk (S23), parallel modeling (S24), and asking group members to explain and give examples (S25). Interpreting actions and talk (S23) emerged as the support Group 2 needed most, which was often followed by further encouragement for the group to do parallel modeling.

3.2. Discussion

In this study, both groups, despite consisting of preservice teachers with underperforming levels in mathematical problem-solving, were able to successfully solve the given problem. This outcome supports Barron (2000) assertion that prior individual achievements of group members are not necessarily predictive of success in collaborative problem-solving. Rather, the key to effective group problem-solving lies in partner responsiveness—defined as the ability of group members to actively listen, consider, and respond to each other's ideas (Sun et al., 2022). Such responsiveness is crucial for the group's ability to absorb and document correct ideas (Reynolds et al., 2020). Partner responsiveness operates through cognitive elaboration, where idea exchange prompts individuals to verbally refine, justify, and extend their reasoning. It also contributes to the regulation of social–emotional dynamics within the group by creating a psychologically safe atmosphere where members feel acknowledged and encouraging active participation. Additionally, responsiveness supports the negotiation of ideas by enabling members to challenge assumptions, evaluate alternative strategies, and converge on shared solutions through consensus-building rather than dominance or passive acceptance.

The structure of the groups, consisting of members with similar ability levels, likely facilitated open dialogue and collaborative processing. When group members exhibit comparable performance levels, it is easier for participants to engage fully in discussions, as they are more likely to feel confident in contributing and sharing ideas. This group structure allowed for a more fluid exchange of insights, enabling participants to build on one another's thinking and fostering a mutually supportive problem-solving environment (Kerrissey et al., 2021; Tang et al., 2024). Still, it is also possible that equal-level grouping reduced status pressure and performance anxiety, which may have contributed independently to group success, indicating that ability-homogeneity must be understood as part of a broader system of social-affective influences rather than as a singular variable.

Collaboration within both groups began with foundational scaffolding, which was perceived by participants as helpful, allowing them to demonstrate an understanding of their roles and communicate the actions they intended to take or were currently undertaking. By the end of the collaboration, we observed explicit empirical indicators of monitoring and reflection in the promoters group, such as verbally revisiting earlier steps ("Let's check if the apex height fits our model"), verifying assumptions, questioning results, and articulating justifications before finalizing conclusions. In contrast, the underperforming passives group did not engage in monitoring or evaluation; instead, they primarily focused on planning and executing the tasks, communicating with team members about the steps they were carrying out. Thus, our interpretation of "monitoring cycles" is grounded in observable linguistic and behavioral markers.

A recurring pattern emerged in their collaborative problem-solving processes, which aligns with these behaviors. The underperforming promoters group consistently engaged in cycles of monitoring and refining their shared understanding of the task. This mechanism appears to involve iterative checking of intermediate mathematical claims and model adjustments, which likely supported error detection and conceptual alignment among members. In other words, repeated monitoring may have facilitated accuracy through incremental validation. In contrast, the underperforming passives group largely concentrated on the sequential implementation of their plans, with little attention to reflection or evaluation. Given the critical role of monitoring in collaborative problem-solving (Haataja et al., 2021), it is essential to encourage the underperforming passives group to actively monitor and reflect on their work. Fostering such metacognitive habits will help them develop the skills necessary to approach increasingly complex problems and improve their overall problem-solving capacity (Shekh-Abed, 2025).

Throughout their collaborative problem-solving process, both groups faced various challenges. During these moments, the instructor's presence was pivotal in providing scaffolding to ensure that the collaboration continued effectively. The instructor's critical role was apparent from the outset, as she facilitated peer collaboration and guided the groups through the problem-solving process (Lin et al., 2021). In practice, the instructor provided concrete reviewing scaffolds, such as asking clarifying questions ("What value did you use for the coordinate of the apex?"), prompting them to revisit prior steps ("Can you check whether this one fits the earlier condition?"), and encouraging articulation of reasoning ("Explain why this vertex position works"). These interventions were timed strategically, often after moments of hesitation or confusion, and elicited noticeably more explicit reasoning from students. Moreover, as noted by Shin et al. (2020) and Beck et al. (2020), a consistent pattern emerged regarding the type of scaffolding both groups required: interpreting their actions and discussing their progress. This need aligns with the form of scaffolding known as "reviewing." According to Anghileri (2006), reviewing scaffolding is intended to refocus attention and provide problem solvers with additional opportunities to deepen their understanding of the task. At the same time, the interpretation of these scaffolding moves as beneficial remains tentative, as the present study did not quantify changes in solution accuracy or interaction quality before and after each intervention. The current findings thus speak to observed potential benefits rather than statistically verified instructional effectiveness.

Finally, the challenges encountered by the problem solvers highlight the assertions of Hoek and Seegers (2005), and Lei and Medwell (2021) that collaborative learning does not reduce the teacher or instructor's essential role. On the contrary, the instructor's involvement remains crucial for helping solvers identify core problems and key aspects related to underlying mathematical concepts in this study. However, we refrain from claiming instructional "effectiveness". Instead, our data suggest that instructor involvement may support the collaborative problem-solving in the form of scaffolding by prompting, supporting conceptual clarification and sustaining collaborative momentum.

4. CONCLUSION

This study explored the dynamics of CPS and the scaffolding needs of underperforming promoters and underperforming passives groups among preservice teachers. Overall, the study directly addressed the research objective by identifying how differing engagement in problem-solving stages shapes collaborative performance. The findings revealed several significant insights into how group structures and problem-solving approaches impact the learning process. First, the group composition itself appeared to be a critical factor in fostering effective collaboration. Both groups were composed of underperforming preservice teachers, yet the shared collaborative problem-solving skills and styles among members positively influenced their interaction, creating a supportive and comfortable working environment. Notably, while both groups followed the general framework of collaborative problem-solving, the underperforming promoters successfully engaged in all four problem-solving steps, including monitoring and reflecting, while the underperforming passives group did not complete the final step, indicating a gap in their problem-solving process. This discrepancy suggests that the passives group may require more focused support in reflecting on and evaluating their actions.

Further examination of the groups' problem-solving processes revealed specific patterns that shed light on their collaborative behavior. The underperforming promoters engaged in repeated cycles of monitoring and reflecting, suggesting that they recognized the value of reviewing their actions and adjusting their approach. In contrast, the underperforming passives group showed repetitive cycles of planning and executing, indicating that they struggled to move beyond the execution phase and failed to engage fully in reflective practices. This difference in problem-solving patterns highlights the importance of scaffolding strategies that encourage deeper reflection and evaluation, which are critical to the development of effective problem-solving skills. Both groups also faced common challenges, particularly in interpreting their actions and discussing their approaches. This shared difficulty underscores the need for scaffolding in the form of interpretive dialogues, where learners can articulate and critically assess their strategies and decisions.

While this research provides valuable insights into the collaborative problem-solving dynamics of underperforming preservice teachers, it is not without limitations. The sample size was relatively small, which may limit the generalizability of the findings to broader populations of preservice teachers. Additionally, the study focused primarily on the collaborative interactions within the context of specific problem-solving tasks, without accounting for other variables such as individual differences in cognitive abilities or prior experiences that could influence problem-solving behaviors. Future research should expand the sample size and explore the role of individual differences in collaborative problem-solving, particularly in relation to how various scaffolding techniques might address these differences. Moreover, longitudinal studies could provide a deeper understanding of how collaborative problem-solving skills evolve over time and how sustained scaffolding impacts the development of these skills.

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Declarations

Author Contribution	: RE: Conceptualization, Funding acquisition, Methodology, and Supervision; LDF: Resources, Visualization, and Writing - original draft; RCIP: Formal analysis, Resources, and Writing - review & editing; MAM: Investigation, Methodology, and Resources; KN: Data curation, Investigation, and Project administration; MS: Investigation and Validation.
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