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Prospective Teachers' Perseverance in Collaborative Mathematical Problem Solving Supported by Technology: A Case Study

Dini Kinati Fardah[1], *Yaya Sukjaya Kusumah[2], Turmudi[3], Kusnandi[4]
[1–4] Universitas Pendidikan Indonesia, Bandung, Indonesia
yskusumah@upi.edu

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ABSTRACT Perseverance in problem solving is related to the decisions individuals make when encountering situations in which solutions are not immediately evident. Research on mathematical perseverance has primarily focused on school students, leaving prospective mathematics teachers comparatively underexplored. This study therefore examines final-year prospective mathematics teachers, who occupy a critical transition between learning mathematics and preparing to teach it. Collaborative problem-solving sessions in solving two open-ended problems, with the option to use technology, were video-recorded and analyzed using the frameworks of perseverance as a collective enterprise and the phases of perseverance in the problem-solving process. An open-ended questionnaire was administered after the tasks to explore participants' reasons for their problem-solving behaviors. The findings indicate that the group demonstrated all indicators of collective perseverance, including expressing uncertainty, questioning the efficiency of strategies, clarifying task expectations, and seeking technological support, even though the role and utilization of technology were quite different in the two tasks. From the perspective of perseverance phases, the group proceeds through the entry phase, the initial phase, and the additional phase—though the specific additional elements differ between the two tasks. Technology supported perseverance by facilitating extended exploration and enabling participants to refine and generalize their solutions. Questionnaire responses further showed that calculators and GeoGebra were perceived as helpful, whereas AI-based tools were not used because participants felt capable of completing the tasks independently. These findings highlight the value of providing prospective mathematics teachers with opportunities to engage in collaborative problem solving supported by appropriate technology to foster perseverance and meaningful technology integration.

Keywords: Perseverance, Prospective math teachers; Math problem solving, Technology in problem solving;

INTRODUCTION

In mathematics education, the topic of problem-solving continues to be a lively subject for debate. Studies on mathematical problem-solving continue to evolve. In this era of very sophisticated technology, humans use various methods, tools, and strategies to solve problems. There is an expectation that technology can make tasks easier for people, as well as enhance the educational experience. In mathematics education, technology has been widely used in various innovations, including the design of gamification, learning media, teaching materials, as well as learning environments. This is why it is crucial and pertinent to explore how students tackle mathematical problems using technology (Jacinto & Carreira, 2017b). However, the benefits of technology do not eliminate the cognitive challenges of mathematical problem solving, where learners must still face uncertainty and struggle.

As many experts have defined "problem" as something or a situation where the solution is not immediately apparent, the choices to struggle, avoid, stop, or even give up become very potent options for an individual who is facing it. These decisions fall within the domain of someone's perseverance. Some professionals interpret perseverance through the lens of an individual's experience. This relates to how a person perceives their perseverance within a specific situation (Duckworth et al., 2007; Miele et al., 2022). The statements such as 'I keep working even if the material is difficult', 'I work as hard as possible', 'I try to do my best to acquire the knowledge and skills taught', 'I put forth my best effort' are examples of items that measure someone's perception of their perseverance (Xu et al., 2023). Although in many situations, focusing solely on perception is insufficient to understand how an individual shows their struggle and effort as evidence that they 'persevere'. Consequently, focusing only on dispositions offers an incomplete picture of how perseverance emerges in real time as learners navigate mathematical tasks.

Studied from a process viewpoint, the idea of perseverance is strongly linked to the determination to initiate and sustain a productive struggle even though an individual experiences obstacles, setbacks, or discouragements (DiNapoli, 2023). There are phases of individual perseverance that consist of the entrance phase, initial attempt phase, and additional attempt phase (DiNapoli, 2023). Since many mathematical activities take place in group settings, perseverance should also be regarded as a phenomenon that arises from collaborative interactions.

In the context of collective efforts, Sengupta-Irving & Agarwal (2017) studied perseverance as peers engaging together in productive struggle with effort over time. Moreover, they state that indicators of productive struggle as the characteristics of perseverance as collective enterprise including the emergence of: 1) conflict in declared solution or strategy; 2) declaration of uncertainty about solution or strategy; 3) declaration of inelegant or inefficient strategy; 4) clarification of task expectations or features; and 5) seeking the support (of the teacher) (Sengupta-Irving & Agarwal, 2017). These findings highlight the importance of exploring perseverance in teamwork settings, particularly as collaboration has emerged as a crucial skill in contemporary educational structures.

Together with problem solving, collaboration is one of the essential competencies emphasized in 21st-century education (P21 Partnership For 21st Century Learning, 2007). The Organisation for Economic Co-operation and Development (OECD) introduced collaborative problem solving in PISA 2015, defining it as the capacity of individuals to work together to address a problem (OECD, 2017). However, Yang (2023) noted that collaboration tends to be more effective among adults. Therefore, collaboration will be most beneficial when conducted among adult participants, such as college students. Understanding collaborative problem solving among adult learners is particularly critical when the participants are future educators who will later be expected to cultivate both collaboration and perseverance in their own students.

As adult learners, final-year prospective mathematics teachers occupy a critical stage in teacher development, transitioning from learners of mathematics to future facilitators of mathematical learning. Understanding how they develop perseverance during technology-supported collaborative problem solving is important because these experiences may shape how they later create classroom environments that encourage productive mathematical struggle. Yet, research on mathematical perseverance has focused primarily on school students, leaving prospective teachers largely underexplored, particularly in technology-supported collaborative settings.

Research shows that the use of technology by students by certain age, whether AI-based or not, can increase student engagement and cognitive and affective abilities (Khazanchi et al., 2025; Ma et al., 2024). Moreover, investigating this population during their final thesis project provides an authentic, high-stakes context where perseverance is genuinely tested over an extended period, allowing for observation of sustained effort in the face of complex, ill-structured problems. Despite these considerations, current scholarship on perseverance provides only a partial picture of how these constructs intersect during technology-supported collaborative problem solving.

Over the past ten years, numerous researchers have begun directing their attention towards the concepts of perseverance in mathematics (Bettinger et al., 2018; Miele et al., 2022) and perseverance in mathematical problem-solving (Carbonneau et al., 2020; Das & Ali, 2023; DiNapoli, 2023; Dinapoli & Miller, 2020; Sengupta-Irving & Agarwal, 2017; Wilburne & Dause, 2017). Nonetheless, there is a lack of studies concentrating on perseverance in mathematical collaborative problem-solving utilizing technology, which is the primary focus of this research. Addressing these gaps calls for a study that brings together learners' visible actions, their interactions with others, and their own reflections within a single analytic frame. Accordingly, the study addresses the following research questions:

1. How are the prospective mathematics teachers' productive struggle in solving mathematical problems with the help of technology in a collaborative situation?

2. How are the prospective mathematics teacher's perception about their perseverance in a collaborative problem-solving situation?

RESEARCH METHOD

This is a case study focuses on a single group of four prospective mathematics teachers (labeled as S1, S2, S3, and S4) to allow for an in-depth examination of perseverance and collaborative problem-solving as they unfold in real time. The group was presented with two mathematical problems in the areas of geometry and statistics which use daily life context. Because the study aims to understand processes, not to generalize outcomes, such a focused sample provides the analytic depth needed to capture subtle behaviors, decision-making patterns, and shifts in perseverance that might be overlooked in larger groups. Moreover, final-year students working on their thesis naturally form a cohesive and authentic collaborative unit, making them a suitable context for observing sustained engagement with complex mathematical problems.

Data were collected through collaborative mathematical problem-solving sessions involving two open-ended tasks (geometry and statistics), supported by optional technology use. The primary data sources comprised video recordings of group interactions, participants' written solutions, and responses to an open-ended questionnaire administered after task completion. Data were analyzed using the frameworks of *perseverance as a collective enterprise* and *the phases of perseverance in a problem-solving process* to identify and interpret participants' perseverance behaviors during collaboration.

In the situation of Collaborative Problem Solving (CPS) with the option to use technology (AI and non-AI), their perseverance was observed and analyzed based on the framework of perseverance as a collective enterprise (Sengupta-Irving & Agarwal, 2017) consisting: 1) Conflict in declared solution or strategy (coded to A); 2) Declaration of uncertainty about the solution or strategy (coded to B); 3) Declaration of inelegant or inefficient strategy (coded to C); 4) Clarification of task expectations or features (coded to D); and 5) Seeking technology support (coded to E). The fifth indicator modification is needed as this study focuses on observing the group performance aided by technology without teacher intervention. Moreover, the group perseverance was also analyzed according to the phase experienced that referred to the perseverance phase, consisting entrance phase, initial attempt phase, and additional attempt phase (DiNapoli, 2023). The problems given to the groups are as seen in Figure 1. To explore students reasoning in doing/avoid some steps, an open-ended questionnaires given as it is claimed effective to understand students' belief and perspective (de Lemos et al., 2023).

JURNAL ABSIS
Jurnal Pendidikan Matematika dan Matematika
Vol. 9 No. 2, August 2026

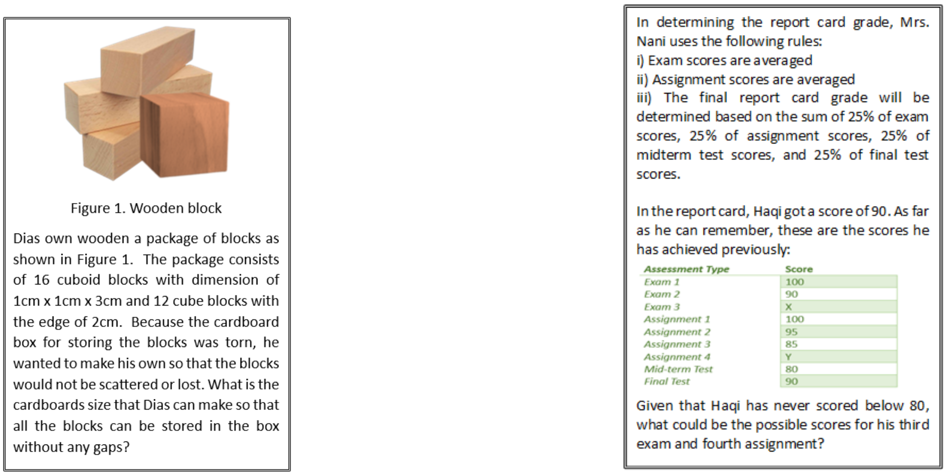


Figure 1. Wooden block

Dias own wooden a package of blocks as shown in Figure 1. The package consists of 16 cuboid blocks with dimension of 1cm x 1cm x 3cm and 12 cube blocks with the edge of 2cm. Because the cardboard box for storing the blocks was torn, he wanted to make his own so that the blocks would not be scattered or lost. What is the cardboards size that Dias can make so that all the blocks can be stored in the box without any gaps?

In determining the report card grade, Mrs. Nani uses the following rules:
i) Exam scores are averaged
ii) Assignment scores are averaged
iii) The final report card grade will be determined based on the sum of 25% of exam scores, 25% of assignment scores, 25% of midterm test scores, and 25% of final test scores.

In the report card, Haqi got a score of 90. As far as he can remember, these are the scores he has achieved previously:

Assessment Type	Score
Exam 1	100
Exam 2	90
Exam 3	X
Assignment 1	100
Assignment 2	95
Assignment 3	85
Assignment 4	Y
Mid-term Test	80
Final Test	90

Given that Haqi has never scored below 80, what could be the possible scores for his third exam and fourth assignment?

(a) (b)

Figure 1. Mathematical task given to the group of math prospective teachers in geometry (a) and statistics (b)

The credibility of the findings was enhanced through source triangulation by comparing evidence across three data sources: video recordings, participants' written work, and questionnaire responses. The convergence of these sources enabled a more comprehensive interpretation of participants' perseverance behaviors and strengthened the trustworthiness of the findings.

RESULTS AND DISCUSSION

The results are presented using two complementary analytical frameworks: the phases of perseverance in the problem-solving process and perseverance as a collective enterprise. The first framework comprises the entrance, initial attempt, and additional attempt(s) phases, whereas the second examines five indicators: conflict in declared solutions or strategies, uncertainty about solutions or strategies, declarations of inelegant or inefficient strategies, clarification of task expectations or features, and seeking technology support.

Prospective mathematics teachers' perseverance in solving mathematical problems with the help of technology in a collaborative situation

The entrance phase

The entrance phase for the two problems given (geometry and statistics) begins with prospective teachers aligning perceptions among members regarding the purpose of the problem, including known information, the objectives to be achieved (both general and specific or sub-objectives), and understanding that these objectives cannot be achieved by directly carrying out certain procedures. The distinction lies in the fact that in the geometry problem, the initial phase is heavily influenced by a lot of discussion, particularly concerning the assumptions established when grasping the problem, as well as in the conception of the strategy employed. In contrast, the statistics task tends to have a more consistent understanding from the outset of engaging in this phase. In the geometry task, the teachers required a considerable amount of time to reach a shared understanding of the problem and the strategies involved; consequently, many indicators of perseverance as collective enterprise emerged. In contrast, for the statistics task, the teachers were in general agreement from the outset to begin by formulating a mathematical model.

The illustration of the emergence of the four indicators when solving the geometry problem shown by the transcripts of their conversation shown by Figure 2. C1 and C2 are codes for the emergence of the same indicator (clarification of task expectations or features), but for different sub-indicators.

S1-1	:	*"...This means we look for the volume of a cube and the volume of a cuboid, then add them up, right?"*	
S2-1	:	*"It seems so, then multiply it by 16..."*	
S1-2	:	*"Huh, are you sure we have to multiply it by 16?"*	*B1*
S2-2	:	*"Yeah, it is because there are 16 blocks...and 12 cubes."*	
S1-3	:	*"Oh yeah, that's right then."*	
S3-1	:	*"This means we just have to stack the cubes and blocks like that, then look for the size."*	*C1*
S1-4	:	*"Wait... but there's no guarantee that there won't be any gaps if you just stack them like that."*	*A1*
S2-3	:	*"Oh yeah, that's right. What does this 'cardboard size' mean? Does it mean that we have to look for the surface area?"*	*C2*
S1-5	:	*"Nope. The size of the cardboard box is meant to be like this, right? 1cmx1cmx3cm." (while pointing to the size of the block in the question)*	*D1*
S4-1	:	*"That means we are looking for a cardboard size (rectangular prism-shaped) that can fit all the blocks without any gaps, right?"*	*D2*

Figure 2. The group discussion in solving geometry problem as evidence of the emergence of perseverance indicators

During the problem understanding and strategy formulation phase, the prospective teachers engaged in active discussions while making written notes. In conversation S1-2, S1 initially questioned S2's claim that the combined volume of the cube and cuboid should be multiplied by 16 (B1), but accepted the idea after S2 provided further explanation. Later, in conversation S1-4, S1 rejected S3's proposal to simply stack all cubes

JURNAL ABSIS
Jurnal Pendidikan Matematika dan Matematika
Vol. 9 No. 2, August 2026

and cuboids (A1), arguing that this approach did not satisfy the requirement of fitting all objects into the cardboard box without leaving gaps.

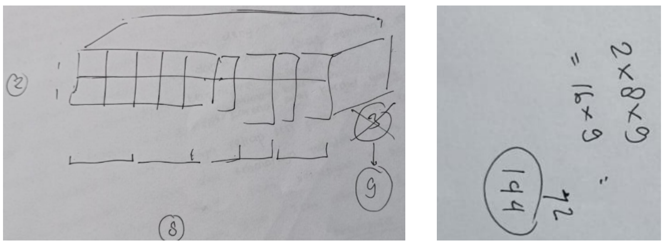
At the entrance phase, two inefficient strategies were proposed. First, S3 suggested solving the problem by directly stacking the cubes and cuboids (C1). Second, S2 proposed determining the surface area of the resulting arrangement (C2). In both cases, other group members demonstrated perseverance by either redirecting the discussion toward the problem goal (D1) or explicitly challenging the proposed idea (A1). These interactions indicate that the prospective teachers initially struggled to establish a shared understanding of the problem requirements and to formulate an appropriate solution strategy.

The initial attempt phase

Next, the prospective teachers moved to the initial attempt phase by implementing the strategy they had collectively agreed upon. For the geometry task, the group agree to arrange the cubes and cuboids so that no gaps remained between them, meanwhile in statistics task, they agree to continue to solve the mathematical model obtained.

In the geometry task, they relied on spatial reasoning to visualize and sketch the arrangement. The first solution obtained, the cardboard size is $2 \times 8 \times 3$. This is not the correct answer, and it is the emergence of the indicators declarations of inelegant solution (C), as illustrated in Figure 3(a). The found their first solution, but it is not the correct solution.

In the statistics assignment, the prospective teachers construct a mathematical model that comprehensively incorporates all the key information provided in the problem. They then proceed to work through the resulting mathematical equations step-by-step, simplifying the expression with each successive line. However, they find their first obstacle here, they found that their constant in the equation results in a negative number (which should be positive). This is a sign of doubt in the model or the steps that have been employed (B). In both problems, the teachers experience the obstacle in the process of solving them. In bring them to enter the next phase, additional attempt phase.



(a) (b)

Figure 3. The group's scratch for the geometry problem solution checking (a) and solution verification (b)

Additional attempt phase 1

In geometry task, the group members realized that $2 \times 8 \times 3$ was just the 1 cm $\times$ 1 cm $\times$ 3 cm blocks arrangement, while the cubes had not been included in the blocks' arrangement. This show the indicator of the uncertainty about solutions (D3) as the member is hesitating the answer. After rediscussing the arrangement of all the blocks including the cubes, they found that the appropriate cardboard size was $2 \times 8 \times 9$. As one of the members asked to check the answer, all of them tried to check each step employed. One of them realized that the $2 \times 8 \times 9$ cardboard or box should have the capacity to load all of the blocks. After checking that the volume of the cardboard matched the total volume of the cuboid blocks and cubes as shown in Fig 3 (b), they did not continue to the next phase (additional attempt phase), even though the solutions to this geometry problem were very diverse and could be divided into several groups of solutions. The prospective teacher group did not use technology at all in this problem and was quite satisfied with finding this one solution. The solving problem process of the geometry task end here.

In statistics task, each member tried to find the error, and one of the teachers finally found that the mathematical model that had been built had not considered the information that each exam and assignment was averaged. This is evidence of the emergence of the clarification of task expectation or feature (D). The prospective teachers are eager to look back at the important information in the problem given.

After the mathematical model was revised by considering all the requirements and important information from the problem, they restarted their efforts to find a solution. This means that the prospective teacher group has entered the first additional attempt phase. They felt confident with the mathematical model they obtained $4x + 3y = 680$ or $y = \frac{680-4x}{3}$. They tried to enter numbers that met the initial requirements given in the problem and obtained ordered pairs (x, y). They did a verification of some value of x that start from 80 and greater (as it is given), and get the value of y which does not meet the condition (the y-value is greater than 100), for example $(80, 120)$, $(85, 113.3)$, $(90, 106.3)$. However, the teachers do not satisfy with the discrete solution. It brought them to additional attempt 2.

The additional attempt phase 2

In statistics problem, after they found that the x and y-value starts to meet the condition $(95, 100)$, the group members got an idea that the solution would be varied because the mathematical model they had compiled led them to a linear equation of two variables. It turns out that this group was not satisfied with the answers they got. They used GeoGebra to get a linear equation visualization of the linear equation they found, and by analyzing the results obtained in the previous phase, they found that the final result they got was an interval for both the x and y values (E). The prospective teachers' scratch to get the general solution aided by GeoGebra is shown in Figure 3. They input

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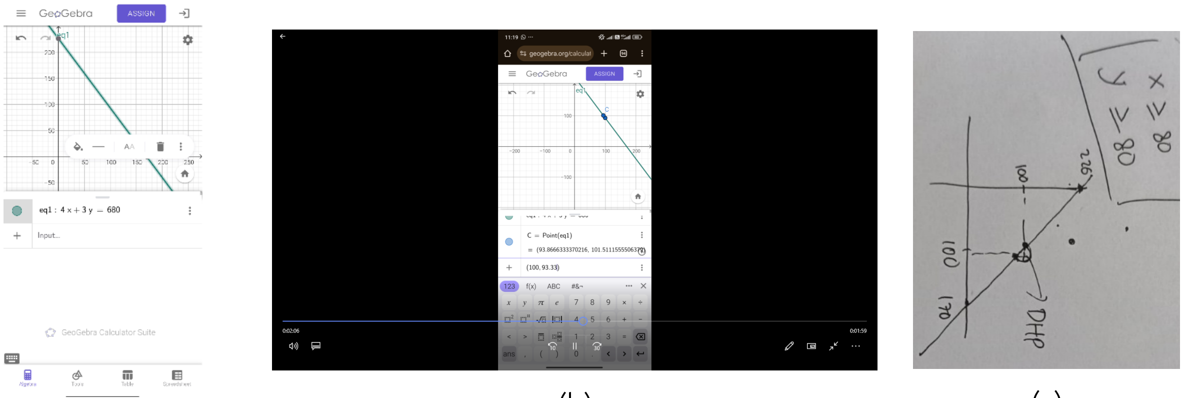
the equation $4x + 3y = 680$ to the GeoGebra and obtain the graph as seen in Fig. 4a, then check some x and y values they found in the previous steps as seen in Fig. 4b. After that, they try to scratch the graph in paper, do the exploration with the value of x, value of y, and the conditions given in the problem ($x \geq 80,\ y \geq 80$), and they find the general solution is in interval of $95 \leq x \leq 100$ and $93.3 \leq y \leq 100$ as seen in Fig. 4c.



(a) (b) (c)

Figure 4. The process of the prospective teachers visualizing the $4x + 3y = 680$ (a), checking one of their answers $(100, 93.3)$ (b), and scratching the general solution (c)

In summary, the emergence of perseverance indicators from the two math problems can be seen in the following Table 1, while the phase of perseverance experienced by the teachers are shown in Table 2. In Table 1 and Table 2 for Geometry problem, it can be seen that the group performs all of the indicators of perseverance and experiences the entrance phase to the initial attempt phase. The solution obtained by the group of prospective teachers is unique. The teachers are not aware of multiple solutions. They stop to explore when they obtain the first and only solution.

Table 1. The emergence of the indicators performed by the group of prospective teachers in solving the problems

Indicators of perseverance as collective enterprise	Geometry	Statistics
Conflict in declared solution or strategy	✓	✓
Declaration of uncertainty about the solution or strategy	✓	✓
Declaration of inelegant or inefficient strategy	✓	✓
Clarification of task expectations or features	✓	✓
Seeking technology support	--	✓

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Table 2. The summary of math prospective teachers' perseverance phase

Perseverance Phases	Geometry	Statistics
Entrance phase	✓	✓
Initial attempt phase	✓	✓
Additional attempt phase-1	✓	✓
Additional attempt phase-2	--	✓

Mathematics teacher's perception about their perseverance in a collaborative problem-solving situation

Students were given a 12-item questionnaire with a Likert scale ranging from 1-5 after completing the task. The data in Table 3 below represents the questionnaire responses of each student in the collaborative group. The table shows that all items had a median score greater than or equal to 4. Except S1 for item number 1 and 5, the students give score 4 or 5 in each questionnaire that means that they agree or strongly agree to the items statement. It shows that the members of the group perceive the same idea that they are persevere in this collaborative problem-solving situation. As seen in the item, the group was eager to give all their effort to each problem even though they find some obstacles. They also agree that when encounter the obstacle, they keep trying, discuss the obstacle with their mates, change the strategy or approach, and some members always come up with the new ideas.

Table 3. The prospective teachers' perception about their perseverance when dealing with problems

No	Questionnaire items	Median	Range Score	Notes
1	When I'm faced with a problem, I'm immediately drawn to it.	4,5	3-5	High variation
2	Every member of the group tries to solve each problem.	4	4-5	3 students chose 4
3	Some members eager to get involved at all in solving the problem	5	4-5	3 students chose 5
4	Some members focus only to the things related to solving the problem	4,5	4-5	Two students chose 5
5	After reading the problem, I usually immediately start scribbling to find a way or answer.	4	2-4	Three students chose 4
6	When I encounter obstacles in finding the answer, I try to change my approach.	4	4	All students chose 4
7	Even though I encounter obstacles, I keep fighting to solve the problem.	4	4-5	Three students chose 4

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No	Questionnaire items	Median	Range Score	Notes
8	When I encounter obstacles, I discuss the obstacles I'm facing with my friends.	4	4	All students chose 4
9	My group members don't give up easily when they haven't found the answer.	5	4-5	Three students chose 5
10	My group members support each other to solve each problem.	5	4-5	Three students chose 5
11	We solve the obstacles our group encounters in finding the answer one by one.	4,5	4-5	Two students chose 5
12	When we're stuck for ideas, each member tries to come up with another idea.	4,5	4-5	Two students chose 5

Alongside the questionnaire, students were also presented with open-ended questions about the tools utilization during the assignments completing. These questions focused on the types of technology they employed, its function, and the motivations behind its use. Firstly, the answer shows that students frequently depend on calculators, particularly for the second problem. For the first problem, they depend on the paper and pencil work, while for the statistics problem they need calculator even for simple calculation. Another tool used by them is GeoGebra. Both of the tools were accessed via their smartphone. Secondly, they explain how the tools help them solving the problems and what will might happened if they do not use them.

> *"The calculator helps us perform calculations quickly and accurately, while GeoGebra helps us check answers graphically and check the solution set of inequalities. If we don't use these tools, calculations may take a little longer or be inaccurate, and the answers cannot be checked in a timely manner."*

This shows that their reliance on calculators was not due to an inability to calculate but rather because they believed that using a calculator made their tasks more efficient and quicker.

Lastly, as they did not rely on AI at all, they claiming that the mathematical problems they received were still clear. They had not encountered a situation where they felt the need to consult AI. If they had used AI, they indicated it would have been to distill the key points and essence of the mathematical problems (due to their length), provide hints, or verify the correctness of their solutions. Meanwhile, if they were asked to involve AI-based technology to solve the problem, they give explanation of how they will use it.

> *"Perhaps ChatGPT can be used to find clues, necessary information, or check existing answers. Furthermore, because the mathematical problem presented*

> *is quite lengthy, I might ask the AI only the main points of the problem presented and find the right solution, along with possible alternative solutions and the thought process. AI technology might also be used to verify the accuracy of the answer I obtained."*

The answer annunciate that they know the potential to use AI, yet they feel no need to involve it. However, when the problem can be understood, they give a brief overview of ideas on how to use AI to help them solve those problems.

Perseverance has been shown to be closely related to problem solving in several prior studies. The present findings show that prospective teachers persevered through all problems until reaching a final solution, although the characteristics of their perseverance differed across problem contexts. In the geometry task, they did not take advantage of the opportunity to use technology, and their final solution did not indicate an awareness that multiple valid solutions could exist. In contrast, while solving the statistics task, they explicitly recognized the possibility of multiple solutions. To derive a more general solution, they employed two types of technology: a calculator to facilitate calculations and support exploration, and GeoGebra to construct and verify a comprehensive solution. This comparison suggests that technology enriched their collaborative problem-solving process, particularly during the exploration, implementation, and verification stages.

This finding is consistent with the technology-assisted problem-solving model proposed by Jacinto & Carreira (2017a), which positions technology as supporting the integration, exploration, and verification stages of mathematical problem solving. In the present study, technology also appeared to encourage perseverance during collaborative problem solving. Providing challenging and non-procedural mathematical problems while allowing students the freedom to use technology can be interpreted as providing support for perseverance (Dinapoli & Miller, 2020). Even after obtaining a promising solution using paper-and-pencil strategies, supported only by a calculator for computation, the prospective teachers voluntarily continued exploring with GeoGebra to refine and generalize their solution. Their decision to make this additional attempt was not driven by failure or discouragement, but rather by the need to improve the quality and completeness of their solution. This differs from DiNapoli's (2019, 2023) description of the *additional attempt* phase, which typically occurs after encountering obstacles or setbacks. Instead, the prospective teachers recognized the need for technological support and deliberately selected GeoGebra because they knew it could facilitate graph construction and help them obtain a more general solution. In comparison, although they had a similar opportunity to use GeoGebra 3D or other applications in the geometry task, they chose not to do so. This pattern supports the view that seeking technological support is one indicator of productive struggle as a component of perseverance (Sengupta-Irving

& Agarwal, 2017). In this context, technology encouraged perseverance not only by accelerating calculations but also by sustaining exploration and improving the quality of the final solution.

The absence of AI-based tools provides another interesting perspective on prospective teachers' perseverance. Although students were free to use AI tools, they did not perceive a need to do so. This finding aligns with Al-Mamary et al. (2024), who reported that students are more likely to use ChatGPT when they perceive it as meeting their learning needs. The prospective teachers in this study were aware that AI tools could potentially assist with some subtasks and were permitted to use them, yet they deliberately chose not to. This decision does not appear to be explained by concerns about the mathematical accuracy of AI tools (Memiş, 2025; Rofiki & Dewi, 2024) or by a lack of trust, as reported in previous studies (Stojanov et al., 2024). Rather, they simply did not consider AI necessary for accomplishing the tasks. Instead of relying on AI, they preferred technological tools that directly supported mathematical exploration and visualization while maintaining their own control over the problem-solving process.

The findings extend current understanding of perseverance by illustrating how it emerges through collaborative interaction and technology-supported problem solving rather than solely as an individual disposition. For mathematics teacher education, these findings suggest the importance of providing prospective teachers with authentic collaborative problem-solving experiences in which technology is used to explore, test, and refine mathematical ideas. Such experiences may help prospective teachers develop not only perseverance but also a deeper understanding of how technology can support productive struggle and collaborative reasoning. This understanding may subsequently inform their future classroom practice by encouraging the design of learning environments that promote persistence, meaningful technology use, and collaborative mathematical reasoning.

CONCLUSION

Studying students' perseverance in mathematical problem solving is important because problem solving is closely related to productive struggle and sustained effort, as reflected in the definition of perseverance. This case study shows that technology supports prospective teachers in extending the problem-solving process and fulfilling all identified indicators of collective perseverance, including conflict in declared solutions or strategies, declaration of uncertainty, declaration of inelegant or inefficient strategies, clarification of task expectations or features, and seeking technological support. The findings also suggest an additional phase in the problem-solving process, in which technology enables prospective teachers to refine and optimize their solutions. These imply that providing prospective teachers with challenging mathematical problems and the freedom to use appropriate technology may help develop their perseverance while promoting meaningful technology integration in mathematics teaching. Such experiences can prepare future teachers to use technology not only to obtain solutions but also to support mathematical exploration, verification, and refinement. Nevertheless, this study is limited by its case study design and the small number of participants. Future research should investigate the role of technology in supporting perseverance across different educational levels and group characteristics and combine observations with interviews to gain a deeper understanding of students' perseverance.

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