

Metacognitive Regulation in Probability and Statistics Problem-Solving: A Phenomenological Study of Distance Mathematics Education Students

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ABSTRACT

This study investigated how Ghanaian distance education students use metacognitive strategies in solving probability and statistics problems. Using a phenomenological qualitative design, 11 first-year Bachelor of Science in Mathematics Education students from three public universities were purposively selected across modular, online, and blended learning modes. Semi-structured online interviews captured experiences of planning, monitoring, and evaluating during problem-solving. Findings showed that students engaged in metacognitive regulation, though unevenly. Planning was dominant, especially in interpreting problems and recalling prior knowledge. Monitoring was selective, influenced by confidence and cognitive load, while evaluation involved checking plausibility and relevance of solutions. Learning modality shaped engagement: modular learning encouraged careful planning, online learning heightened self-checking, and blended learning supported balanced regulation through feedback. Structural and emotional constraints, including limited feedback, connectivity issues, and anxiety, reduced effective engagement. The study proposes a contextualised model linking learning modality and structural factors to self-regulated learning theory.

Keywords: Distance learning, Metacognition, Phenomenology, Probability and statistics, Undergraduate mathematics education

INTRODUCTION

More people are studying at a distance than ever before. That is true globally, and it is true in Ghana too. The reasons are not hard to see. Distance programmes bring in working adults, reach students who live far from campuses, and help fill teacher shortages. The Ghana Tertiary Education Commission (GTEC) has pushed for better quality assurance in Open and Distance Learning (ODL) (Graphic Online, 2025; GTEC, 2023). But quality is not just about policy. It is about what happens when a student sits alone with a module, an internet connection that may or may not work, and a statistics problem that does not make sense.

Probability and statistics form a critical component of mathematics teacher education in Ghana, intersecting conceptual reasoning, probabilistic inference, data interpretation, and decision-making. National curriculum reforms emphasise competencies such as reasoning, problem-solving, and the capacity to apply mathematical concepts in real-world contexts (National Council for Curriculum and Assessment [NaCCA], 2023; 2024). For students studying at a distance, these competencies must be developed within learning environments that differ markedly from traditional classrooms. In distance learning contexts, instruction is typically mediated through textual modules, online platforms, and periodic tutorials rather than continuous face-to-face engagement. Compounding this complexity, evidence from Ghanaian ODL contexts reveals structural challenges such as digital connectivity limitations, variability in platform usability, and uneven access to academic support, all of which can shape how students engage with content and regulate their own learning (Kammer et al., 2025; Sarpong, 2023).

Within mathematics education research, metacognition has consistently emerged as a pivotal construct for explaining how learners plan, monitor, and evaluate their problem-solving processes. Metacognitive regulation, involving intentional oversight of one's cognitive strategies, has been shown to underpin deeper conceptual understanding and improved mathematics performance (Hidayat et al., 2025). In addition, recent research on

self-regulated learning in Ghanaian ODL contexts highlights the importance of learners' strategic regulation for academic success (Kayi & Van Wyk, 2025). These insights are especially salient for probability and statistics, which require procedural knowledge and the ability to make sense of uncertainty, recognise underlying structures, and critically assess solution pathways.

While metacognition has been widely examined in mathematics education, three limitations remain evident in the literature. First, most studies rely on quantitative instruments that measure frequency of strategy use rather than capturing the lived structure of metacognitive experience. Second, research on metacognition in probability and statistics has predominantly been conducted in face-to-face settings, leaving modality-specific influences under-theorized. Third, little is known about how structural constraints common in sub-Saharan African distance education contexts interact with learners' regulatory processes. Consequently, what remains insufficiently understood is not whether students use metacognitive strategies, but how these strategies are experienced, shaped, and transformed within multimodal distance environments. Addressing this gap is theoretically important because it challenges decontextualised models of metacognition and situates regulatory processes within instructional structures.

This study addresses this gap by exploring the lived experiences of first-year BSc Mathematics Education students in Ghana as they confront probability and statistics problems within distance learning environments. Through in-depth narratives, this study examines how learners deploy metacognitive strategies namely, planning, monitoring, and evaluating when solving statistical problems. It further explores how these strategies are shaped by the affordances and constraints of their learning modalities. Specifically, the study aims to (a) describe the specific metacognitive strategies students use in statistical problem-solving, (b) elucidate how modality influences these strategies, and (c) uncover students' perceptions of factors that support or hinder their metacognitive engagement. In doing so, the research contributes locally grounded evidence to global discussions on metacognition in mathematics education and offers actionable implications for curriculum designers, distance education practitioners, and teacher educators in Ghana and similar contexts.

THEORETICAL BACKGROUND

Metacognition has been widely recognised as a central construct in understanding how learners regulate their thinking during complex cognitive tasks. Originally introduced by Flavell (1979), metacognition refers to individuals' awareness of their cognitive processes and their ability to monitor and control those processes in goal-directed activity. Literature extends this view by emphasising metacognition as an active and dynamic form of cognitive regulation rather than a static body of knowledge (Halmo et al., 2024; Österholm et al., 2025; Zimmerman, 2002).

In educational contexts, metacognition is commonly conceptualised as comprising two interrelated components: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to what learners know about themselves as learners, about tasks, and about strategies, while metacognitive regulation involves the deliberate actions learners take to plan, monitor, and evaluate their cognitive activities (Schraw, 1998). These components are mutually reinforcing; learners draw on their metacognitive knowledge to regulate learning, and regulation in turn refines their knowledge of what works, when, and why.

Within problem-solving contexts, metacognition has been shown to distinguish expert from novice performance. Learners who engage metacognitively are more likely to interpret problems accurately, select appropriate strategies, recognise errors, and adjust approaches when initial attempts fail (Schoenfeld, 2016). Rather than proceeding mechanically, such learners remain reflective throughout the problem-solving process. This perspective is particularly relevant to mathematics education, where success often depends on strategic thinking and self-monitoring rather than rote learning.

Recent syntheses and meta-analyses confirm the educational significance of metacognition. Studies consistently report moderate to strong effects of metacognitive instruction on learners' academic achievement, particularly in mathematics and science (Hidayat et al., 2025; Österholm et al., 2025). These findings underscore the importance of examining whether learners possess metacognitive skills and also how these skills are enacted in specific disciplinary and instructional contexts.

Metacognitive Strategies in Mathematical, Probabilistic, and Statistical Problem-solving

In mathematics education research, three core strategies, namely planning, monitoring, and evaluation are consistently identified as central to effective problem-solving (Hanifa et al., 2025; Polya, 1973; Zhao & Saleh, 2025). *Planning* involves analysing the problem, identifying relevant information, recalling prior knowledge, and selecting an initial approach. In mathematics, planning allows learners to interpret problem structure, anticipate solution pathways, and avoid premature computation. *Monitoring* entails ongoing awareness of one's progress during problem-solving, including checking calculations, questioning assumptions, and recognising inconsistencies. *Evaluation* occurs after or sometimes during problem-solving and involves judging the reasonableness of solutions, reflecting on strategy effectiveness, and considering alternative approaches (Hanifa et al., 2025; Zhao & Saleh, 2025).

In probability and statistics, metacognitive strategies take on particular importance due to the non-deterministic and interpretive nature of the discipline. Unlike procedural domains of mathematics, statistical problem-solving often requires learners to reason under uncertainty, interpret contextual information, and justify conclusions rather than simply compute answers. Research on probabilistic thinking among prospective mathematics teachers indicates that learners who engage in explicit planning and evaluation are better able to avoid common misconceptions, such as misinterpreting probabilities or overgeneralising from limited data (Supratman et al., 2025).

Studies combining problem-solving tasks with reflective interviews further show that metacognitive strategy use in statistics is highly situational. Learners may plan carefully when problems are unfamiliar but rely on automatic strategies for routine tasks. Similarly, monitoring may intensify when confidence is low or when solutions appear counterintuitive (Toikka et al., 2024). These findings suggest that metacognition in statistical problem-solving is adaptive and responsive to task demands, reinforcing the need for qualitative approaches that capture learners' lived experiences.

Metacognition, Self-regulated Learning, and Distance Education

Metacognition is closely linked to broader theories of self-regulated learning (SRL), which conceptualise learners as active agents who set goals, employ strategies, monitor progress, and reflect on outcomes (Zimmerman, 2002). In SRL models, metacognitive regulation plays a central role, particularly in learning environments where external guidance is limited. Distance education contexts place heightened demands on learners' self-regulatory and metacognitive capacities. Without continuous face-to-face interaction, learners must independently manage their learning, interpret instructional materials, and evaluate their understanding. Research across distance and online learning environments consistently highlights metacognition as a critical predictor of persistence, engagement, and academic success (Bol & Garner, 2011; Kayi & Van Wyk, 2025).

In Ghanaian distance education, studies on self-regulated learning suggest that students' ability to plan and monitor their learning activities significantly influences academic performance (Kayi & Van Wyk, 2025). However, such studies often examine learning strategies at a general level, without focusing on how metacognition operates during discipline-specific tasks such as mathematics or statistics problem-solving. This represents a notable gap, given the cognitive complexity of these subjects.

Furthermore, distance learning is not a uniform experience. Modular, online, and blended learning environments differ in terms of instructional immediacy, feedback mechanisms, and opportunities for interaction. These differences can shape how learners deploy metacognitive strategies. For instance, limited feedback in modular learning may encourage greater reliance on evaluation at the end of problem-solving, while online environments may prompt continuous monitoring due to exposure to multiple solution approaches. Yet, empirical research that explicitly examines how different distance learning modalities influence metacognitive engagement in mathematics remains limited.

Not everyone agrees that metacognition is the key to better learning. Some researchers argue that the construct is too vague, that it is difficult to measure separately from cognition, and that training learners to be more metacognitive does not always translate into better performance (Veenman et al., 2006). Others point out that

metacognitive strategies that work in face-to-face settings may not transfer easily to distance environments where feedback is delayed. I take these concerns seriously. The goal of this study is not to prove that metacognition matters but to understand how students themselves describe using these strategies under real distance learning conditions.

METHOD

Research Design

This study employed a phenomenological qualitative research design. Phenomenology focuses on describing individuals' lived experiences of a phenomenon as perceived and articulated by the participants themselves (Creswell & Poth, 2018). This design was appropriate for the study because it sought to understand how distance education students experience and use metacognitive strategies while solving probability and statistics problems, rather than to measure or predict outcomes. By adopting a phenomenological approach, the study was able to capture students' subjective meanings and reflections on planning, monitoring, and evaluating their problem-solving processes within different distance learning modalities. This design therefore aligned with the study's aim of exploring metacognitive strategy use as it is lived and experienced in Ghanaian distance mathematics education contexts.

Researcher Positionality and Bracketing

As the researcher is a mathematics education scholar with experience teaching probability and statistics in distance learning contexts, reflexive awareness was necessary to prevent prior assumptions from shaping interpretation. In line with phenomenological methodology (Creswell & Poth, 2018), bracketing (*epoché*) was undertaken to suspend preconceptions about how metacognition should manifest in statistical problem-solving. Prior to data collection, the researcher documented personal beliefs regarding students' expected strategy use and revisited these memos throughout analysis to ensure that themes were grounded in participants' lived descriptions rather than theoretical expectations. Reflexive journaling was maintained during coding to critically interrogate interpretive decisions and preserve fidelity to participants' meanings.

Participants

Participants were 11 undergraduate students enrolled in a Bachelor of Science (BSc) in Mathematics Education programme through distance learning at three public universities in Ghana (University A, $n = 3$; University B, $n = 4$; University C, $n = 4$). The sample comprised 5 females and 6 males, all being first-year (Level 100) students who had completed a Probability and Statistics course. The students were selected using purposive sampling, which is appropriate for phenomenological research where participants are chosen based on their direct experience with the phenomenon under investigation (Creswell & Poth, 2018).

Purposive sampling employed was based on three criteria: (a) enrollment in a BSc Mathematics Education distance programme, (b) successful completion of a Probability and Statistics course, and (c) representation across the three main distance learning modalities namely, modular, online, and blended. Sampling continued until information richness was achieved, determined by the recurrence of themes across interviews without new insights emerging. The sample size aligns with phenomenological recommendations, which typically range from 5 to 25 participants (Polkinghorne, 1989, as cited in Creswell, 2007).

Data Collection

Data were collected through in-depth, semi-structured online interviews conducted via Google Meet. This platform was chosen given the distance learning context of the study and the geographical dispersion of participants across different regions of Ghana. Interviews were scheduled at times convenient for participants to ensure flexibility and maximize participation.

An interview guide was developed in alignment with the study objectives, consisting of open-ended prompts such as, "Can you walk me through how you started solving a recent statistics problem?" and "What did you do

when you felt stuck?” Probing questions, including “You mentioned checking your work — what exactly were you looking for?” were used to encourage deeper reflection and clarification. Each first-phase interview lasted between 45 and 70 minutes.

Data collection occurred in two phases. In the first phase, all 11 participants took part in individual interviews focusing on their general experiences of probabilistic and statistical problem-solving and the metacognitive strategies they employed. Following a preliminary review of these interviews, a second phase was conducted with four participants whose initial responses provided particularly rich and reflective accounts. These follow-up interviews, lasting 30 to 45 minutes each, allowed for deeper exploration of emerging ideas and clarification of key aspects of participants’ experiences. With participants’ informed consent, all interviews were audio-recorded and later transcribed verbatim to ensure accuracy and completeness of the data.

Trustworthiness of the Study

Trustworthiness was ensured through strategies aligned with qualitative rigor criteria (Lincoln & Guba, 1985). *Credibility* was enhanced through three measures. First, prolonged engagement was achieved by spending approximately 12 hours per transcript through repeated listening, reading, and analysis. Second, peer debriefing was conducted with a colleague experienced in qualitative research, who reviewed coding decisions and theme development, challenging interpretations and confirming emergent patterns. Third, member checking was performed by returning interview summaries to four participants who had provided particularly rich accounts; all confirmed the accuracy of their representations, with two offering minor clarifications that were incorporated. *Dependability* was addressed by maintaining a detailed audit trail documenting all analytic decisions, including initial coding schemes, theme refinement logs, and rationale for collapsing meaning units. This trail allowed for external review of the research process. *Confirmability* was supported through reflexive journaling, with 15 entries written across the analysis period. These entries recorded the researcher’s evolving interpretations, documented bracketing efforts to suspend preconceptions about metacognitive strategy use, and critically interrogated how personal assumptions might shape theme development. *Transferability* was facilitated through thick description of participants, institutional contexts, modality differences, and the distance learning environment, allowing readers to determine applicability of findings to similar contexts.

Data Analysis

Data analysis followed phenomenological procedures aimed at identifying the essence of participants’ lived experience (Creswell & Poth, 2018; Moustakas, 1994). Analysis proceeded in four iterative steps. First, all transcripts were read multiple times to gain holistic familiarity with each participant’s account. Second, horizontalisation was performed, in which each statement relevant to the experience of metacognitive engagement was treated as having equal value. This process identified 187 significant statements, which were extracted from the transcripts. Third, these statements were grouped into preliminary meaning units (e.g., “reading problems repeatedly,” “stopping to check formulas,” “doubting answers after online search”). Through discussion between the researcher and a peer debriefer, similar units were collapsed into broader themes reflecting shared aspects of the experience. NVivo 14 software was used to organize and retrieve coded segments. Fourth, through phenomenological reduction, the researcher moved iteratively between individual descriptions to produce textural descriptions (what participants experienced) and structural descriptions (how contextual and modality-related conditions shaped those experiences). Finally, textural and structural descriptions were synthesized to produce a composite essence of metacognitive strategy use among distance students in probability and statistics. Reflexive journaling was maintained throughout coding to critically interrogate interpretive decisions and preserve fidelity to participants’ meanings.

RESULTS

This section presents the findings from the phenomenological analysis of interview data. The results are organised according to the study objectives and are presented through thematic narration supported by participants’ verbatim accounts. Three major themes emerged: (1) metacognitive strategies used in statistical problem-solving, (2) the influence of distance learning modality on metacognitive strategy use, and (3) perceived factors that support or hinder metacognitive engagement.

Metacognitive Strategies Used in Solving Probability and Statistics Problems

Participants' accounts revealed that metacognitive engagement in probability and statistics problem-solving was primarily manifested through planning, monitoring, and evaluating, though the way these strategies were enacted varied across individuals.

Planning as Uncertainty Reduction

When participants were given probability or statistics problems, the first action most described was making sense of the problem before attempting any calculation. Planning involved assessing the difficulty of the problem, identifying what was being asked, and recalling relevant concepts or formulas.

One participant explained:

"First I check. Is this prob or stats? Eh, the thinking is different. So once I know, I know." (S3)

Similarly, another student noted:

"Hmmm! the questions, I usually read two times or more. If I rush, I will pick wrong formula." (S7)

Several students reported that planning also involved recalling prior learning and mentally linking the problem to previously encountered examples.

"I think about similar questions we've done before. If I remember one, then sharp...I know the direction to take." (S2)

In probability questions, planning often involved visualisation or listing of outcomes:

"Sometimes I draw small table like that or write the outcomes so that I don't confuse myself." (S9)

Time management also featured prominently in students' planning, particularly during assessments.

"If I see that the question has many parts, hmmm.... I plan how much time to spend so I don't get locked on one." (S11)

These findings suggest that planning functions not merely as a procedural first step but as a psychological mechanism for reducing ambiguity in statistical reasoning. In distance contexts, where immediate clarification is unavailable, planning assumes a compensatory regulatory role that extends beyond classical models of metacognition.

Monitoring as Cognitive Risk Management

Monitoring emerged as the strategy through which students checked their understanding and progress while solving problems. Many participants described pausing at certain points to verify calculations or reconsider whether their approach still aligned with the question.

One participant stated:

"Normally when I'm calculating probabilities, I stop small to check if the values still make sense, because one mistake can spoil everything." (S6)

Another explained monitoring as checking assumptions:

"Oh yeah! Sometimes I ask myself if the formula I'm using really match the situation, especially statistics questions." (S1)

However, not all students monitored continuously. Some preferred to complete the solution before reviewing it.

“If I stop plenty, I lose my flow. So I solve everything first, then I go back to check.” (S4)

These findings indicate that monitoring in distance statistical problem-solving operates not simply as ongoing checking, but as a form of cognitive risk management. Students engaged in monitoring when they perceived potential error, uncertainty, or misalignment between their reasoning and the problem demands. In contexts characterised by limited immediate feedback, monitoring becomes selectively activated rather than continuous, reflecting learners’ attempts to balance cognitive load with error prevention. This suggests that monitoring in distance environments is shaped by perceived vulnerability and available cognitive resources, thereby extending classical models of metacognition which often portray monitoring as a stable, uninterrupted regulatory process.

Evaluation as Plausibility Testing and Reassurance

Evaluation was consistently described as the final stage of problem-solving. Participants reported checking whether their answers were reasonable, especially in probability questions where values outside expected ranges were immediate suspect.

“If my probability is more than one, Ah! I know something is wrong.” (S8)

Others evaluated by reconnecting the answer to the context of the problem:

“I go back to the question to see if my answer actually answers it, no just calculation.” (S5)

Some students also evaluated their strategies retrospectively:

“Oh yeah! After solving, I think about whether there was an easier way I could have used.” (S10)

The findings further suggest that evaluation functions not merely as a terminal correctness check, but as a plausibility-testing and reassurance mechanism in statistical reasoning. Participants relied on contextual logic, probabilistic boundaries, and strategic reflection to confirm the credibility of their answers. In the absence of immediate instructor validation, evaluation becomes a substitute form of external feedback, enabling students to restore confidence in their reasoning. This reframes evaluation as both a cognitive and affective regulatory act, highlighting its dual role in validating solutions and stabilising learner confidence within distance learning contexts.

Influence of Distance Learning Modality on Metacognitive Strategy Use

Participants’ experiences revealed that distance learning modality shaped how metacognitive strategies were enacted. Students in modular distance learning described heavier reliance on planning and evaluation due to limited real-time support.

“Because the module is what I have, I plan well well before I start. I don’t want to waste time.” (S3)

Students in online distance learning reported frequent monitoring, often prompted by exposure to multiple explanations online.

“Sometimes I check myself more because online you see different methods and you start doubting your own.” (S6)

Participants in blended learning highlighted the role of face-to-face sessions in strengthening confidence.

“When we meet the lecturer, yeah... I see my mistakes. Later when I solve alone, I can check myself better.” (S1)

These findings suggest that modality influences access to resources and students’ metacognitive habits.

Perceived Supports and Constraints to Metacognitive Engagement

Participants identified several factors that influenced their ability to engage metacognitively. Supporting factors included clear examples, peer discussion, and prior exposure to similar problems.

“When I discuss with friends, yes, it makes me rethink my solution.” (S9)

Constraining factors included limited feedback, internet challenges, and anxiety.

“Hmmm! Sometimes I just want to finish because the network is bad, so I don’t even check my work.” (S2)

Others noted that anxiety reduced reflection:

“Eeei! When I panic, hmmm... I skip planning and just calculate.” (S7)

The Essential Structure of the Experience

Consistent with van Manen’s (2016) emphasis on articulating the essence of lived experience, the following synthesis presents the fundamental structure underlying participants’ metacognitive engagement. Across participants’ accounts, the essence of metacognitive engagement in distance probabilistic and statistical problem-solving can be described as a continuous negotiation between uncertainty and self-regulation. Students experienced probability and statistics tasks as cognitively demanding and often ambiguous. In response, they engaged in planning as a stabilizing mechanism, monitoring as a tension-management process, and evaluation as a reassurance strategy. Distance learning conditions intensified this negotiation. In modular environments, regulation was anticipatory; in online environments, it was reactive; in blended environments, it became calibrated through feedback. Thus, metacognitive engagement was not merely the application of strategies but a lived process of sustaining cognitive control in contexts of limited immediacy.

DISCUSSION

This study set out to explore how distance education students experience and enact metacognitive strategies while solving probability and statistics problems, how distance learning modality shapes these strategies, and which factors support or hinder metacognitive engagement. The findings provide a distinct account of metacognition as a *lived cognitive practice*, shaped by disciplinary demands, instructional modality, and learners’ affective and contextual realities.

Metacognitive Strategy Use as Situated Cognitive Regulation in Statistical Problem-solving

Participants’ accounts confirm that planning, monitoring, and evaluation constitute the core structure of metacognitive engagement in probability and statistics problem-solving. This finding is consistent with established models of metacognitive regulation (Hanifa et al., 2025; Zhao & Saleh, 2025; Zimmerman, 2002). However, the present study extends this literature by showing that these processes depend on context, adapt to learners’ situations, and vary across individuals, rather than unfolding in a fixed or uniform way.

Planning emerged as more than an initial step; it functioned as a *sense-making mechanism* through which students attempted to reduce uncertainty inherent in statistical tasks. Unlike purely procedural mathematics problems, probability and statistics require interpretation of contextual information, recognition of assumptions, and anticipation of plausible outcomes. Participants’ emphasis on reading problems repeatedly, classifying question types, and recalling similar examples reflects what Schoenfeld (2016) describes as *strategic orientation*. That is, the ability to frame problems before acting on them. This supports research in statistics education showing that difficulties often arise not from computation but from misinterpretation at the planning stage (Garfield & Ben-Zvi, 2008).

Monitoring, however, was not universally embraced. The variation observed, where some students monitored continuously while others deferred checking until the end suggests that metacognitive strategies are filtered through learners’ perceptions of cognitive cost. For some participants, monitoring served as an error-prevention

mechanism; for others, it was seen as disruptive to reasoning flow. This aligns with research indicating that novice learners may perceive metacognitive monitoring as cognitively taxing, particularly when working memory is already heavily engaged (Sweller et al., 2019). In distance learning contexts, where cognitive load may be worsened by unclear materials or lack of immediate clarification, students may strategically suppress monitoring to preserve momentum, even at the expense of accuracy.

Evaluation was the most consistently enacted strategy, likely because probability and statistics problems offer clear external constraints such as probability values exceeding logical bounds that prompt reflection. This finding supports earlier work suggesting that evaluation is often more accessible to learners than planning or monitoring because it relies on outcome plausibility rather than process awareness (Schraw & Dennison, 1994). Importantly, participants' reflections on the effectiveness of their strategies show developing metacognitive awareness, a key consideration for mathematics education students who will become future teachers.

Distance Learning Modality as a Structuring Condition for Metacognitive Engagement

This study contributes by showing that distance learning does more than provide a setting for learning; it influences how students use metacognitive strategies. Although previous studies suggest that distance learning requires higher levels of self-regulation (Bol & Garner, 2011), the findings here indicate that different learning formats encourage different metacognitive processes.

In modular distance learning, the absence of immediate instructional feedback appears to intensify planning and post-solution evaluation. Students' reliance on careful pre-planning reflects a form of anticipatory regulation, consistent with Zimmerman's (2002) forethought phase of self-regulated learning. However, delayed feedback may also discourage mid-solution monitoring, as learners lack external reference points to validate interim steps. This suggests that modular environments may inadvertently promote *front-loaded* and *back-loaded* metacognition while constraining real-time regulation.

Online distance learning, by contrast, appeared to amplify monitoring behaviours, but not always productively. Exposure to multiple solution methods through online resources triggered frequent self-checking, yet also introduced doubt and cognitive overload. This aligns with findings from online learning research showing that unstructured access to abundant information can undermine metacognitive confidence, particularly among novice learners (Azevedo et al., 2018). In this sense, monitoring was sometimes reactive rather than strategic, driven by uncertainty rather than deliberate control.

Blended distance learning emerged as the most supportive context for balanced metacognitive engagement. Participants described face-to-face or synchronous sessions as spaces for calibrating their thinking; validating planning approaches, clarifying misconceptions, and strengthening criteria for evaluation. These interactions appear to function as *metacognitive scaffolds*, enabling learners to internalize regulatory practices that they later enact independently. This finding reinforces arguments that blended learning can support deeper cognitive regulation when face-to-face components are intentionally designed for reflection rather than content transmission.

Supports and Constraints as Regulators of Metacognitive Access

Students' views of what helped or hindered them show that metacognitive engagement depends on having skills and also on whether those skills can be used in real learning situations. Supports such as worked examples, peer discussion, and familiarity with problem types helped reduce uncertainty and allowed students to focus more on regulating their thinking. Peer interaction was especially important, as it enabled students to reconsider their reasoning through discussion, aligning with socio-cognitive views of metacognition that emphasize reflection through dialogue (Goos et al., 2002; Vygotsky, 1978).

Conversely, constraints such as limited feedback, connectivity challenges, and anxiety directly interfered with metacognitive processes. Time pressure and unstable internet access prompted students to bypass planning and monitoring in favour of rapid completion, illustrating how structural barriers can suppress reflective engagement.

This finding deepens Ghanaian distance education literature by showing that infrastructural challenges do not merely affect participation but shape *how* students think while learning (Kayi & Van Wyk, 2025).

Affective factors, particularly anxiety, played a critical role. Students' reports of "panicking" and rushing through problems echo research linking mathematics anxiety to reduced metacognitive control (Ashcraft & Krause, 2007). Since probability and statistics are often viewed as abstract, anxiety may reduce students' focus and cause them to follow procedures without reflecting on their thinking. This shows that metacognitive processes are closely connected to how students manage their emotions, especially when learning independently.

Toward a Contextualised Model of Metacognitive Regulation in Distance Statistics Learning

Based on the findings, this study proposes a contextualised model in which metacognitive regulation in distance statistics learning operates through three interacting dimensions:

1. Cognitive Dimension (planning, monitoring, evaluation)
2. Modal Dimension (modular, online, blended structures shaping regulatory timing)
3. Affective-Structural Dimension (anxiety, connectivity, feedback availability)

The model suggests that metacognitive effectiveness depends not solely on learners' internal capacity but on the alignment between regulatory demands and instructional modality. This extends traditional SRL models by showing that structural constraints actively shape how students use metacognition.

Implications for Metacognition in Distance Mathematics Teacher Education

Taken together, the findings position metacognition as a context-sensitive practice shaped by modality, task structure, and emotional conditions. For distance mathematics teacher education, this has important implications. If future teachers experience metacognition as optional, disruptive, or inaccessible under pressure, they are less likely to model reflective problem-solving in their own classrooms. The study therefore suggests that distance education programmes should move beyond assuming self-regulation and instead design explicitly for metacognitive engagement. This includes embedding reflective prompts in modules, structuring online spaces to reduce cognitive overload, and using blended sessions as opportunities for metacognitive calibration rather than mere content review. Such design choices are particularly critical in probability and statistics, where reasoning quality depends on interpretation and judgment as much as on computation. By showing students' lived experiences, this study contributes to a deeper theoretical and practical understanding of metacognition in distance mathematics education. It extends phenomenological research by demonstrating how metacognitive strategies are enacted, constrained, and reshaped within specific instructional modalities, offering insights that are directly relevant to both mathematics education theory and distance learning practice.

CONCLUSION

From this study, metacognition in distance probability and statistics learning is not a fixed set of skills. It is a flexible, sometimes fragile response to uncertainty. Students plan, monitor, and evaluate differently depending on their learning modality, their access to feedback, and how anxious they feel. Modular students plan ahead because they have to. Online students check themselves constantly, sometimes too much. Blended students get the benefit of calibration through face-to-face sessions. The model proposed here tries to capture that disorderliness. For distance teacher education, the implication is simple. If we want future teachers to model reflective problem-solving, we cannot assume they will figure it out on their own. We need to design for metacognition deliberately.

LIMITATIONS OF THE STUDY

This study is limited by its small sample size and focus on first-year students, which may not reflect experiences across levels of study. Data relied on self-reported accounts rather than observation of real-time problem-solving,

which may influence recall accuracy. Additionally, while participants were drawn from three universities, findings remain contextually situated within Ghanaian distance education and may not generalize universally.

RECOMMENDATIONS

Based on the findings, it is recommended that distance mathematics education programmes intentionally incorporate metacognitive support into probability and statistics instruction. Instructional materials and learning activities should encourage students to reflect on problem interpretation, solution processes, and answer validity. In addition, distance learning modalities should be designed to provide opportunities for guided reflection and feedback that support metacognitive regulation. It is also recommended that instructors attend to students' reasoning processes in feedback and encourage peer interaction as a means of promoting reflective problem-solving. Future research may extend this study by examining metacognitive strategy use across different levels of study, employing longitudinal designs, or investigating instructional interventions that explicitly target metacognitive development in distance mathematics education.

Ethical approval

Ethical approval for the study was obtained from the University of Education, Winneba. The research was conducted in accordance with the institution's ethical standards and the 1964 Declaration of Helsinki, including its subsequent amendments.

Conflict of interest

There are no conflicts of interest associated with this work.

Data Availability

The anonymised data supporting the findings of this study are available from the author on reasonable request. Data are not publicly available to preserve participant confidentiality.

REFERENCES

1. Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, *14*(2), 243–248. <https://doi.org/10.3758/BF03194059>
2. Azevedo, R., Taub, M., & Mudrick, N. V. (2018). Using multi-channel trace data to infer and foster self-regulated learning between humans and advanced learning technologies. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of Self-Regulation of Learning and Performance* (2nd ed., pp. 254–270). Routledge.
3. Bol, L., & Garner, J. K. (2011). Challenges in supporting self-regulation in distance education environments. *Journal of Computing in Higher Education*, *23*(2), 104–123. <https://doi.org/10.1007/s12528-011-9046-7>
4. Creswell, J. W. (2007). *Qualitative inquiry and research design* (2nd ed.) Sage Publications, Inc.
5. Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.
6. Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, *34*(10), 906–911. <https://doi.org/10.1037/0003-066X.34.10.906>
7. Garfield, J., & Ben-Zvi, D. (2008). *Developing students' statistical reasoning: Connecting research and teaching practice*. Springer.
8. Ghana Tertiary Education Commission. (2023). *Distance education policy audit (Phase 1)*. GTEC, Ghana.
9. Goos, M., Galbraith, P., & Renshaw, P. (2002). Socially mediated metacognition: Creating collaborative zones of proximal development in small group problem solving. *Educational Studies in Mathematics*, *49*(2), 193–223. <https://doi.org/10.1023/A:1016209010120>
10. Graphic Online. (2025, September 10). GTEC launches distance learning policy to improve standards. <https://www.graphic.com.gh/>
11. Halmo, S. M., Yamini, K. A., & Stanton, J. D. (2024). Metacognition and self-efficacy in action: How first-year students monitor and use self-coaching to move past metacognitive discomfort during problem solving. *CBE—Life Sciences Education*, *23*(2), ar13. <https://doi.org/10.1187/cbe.23-08-0158>

12. Hanifa, M., Nursalam, N., Kusumayanti, A., & Suharti, S. (2025). Understanding the influence of metacognition on mathematical literacy: A literature review. *Pedagonal: Jurnal Ilmiah Pendidikan*, 9(2), 188-200. <https://doi.org/10.55215/pedagonal.v9i2.42>
13. Hidayat, R., Mohd Saad, M. R., & Wewe, M. (2025). A meta-analysis of the effect of metacognitive instruction on mathematics achievement. *Cogent Education*, 12(1). 2517510. <https://doi.org/10.1080/2331186X.2025.2517510>
14. Kammer, J., Atiso, K., & Borteye, E. (2025). Internet policy and connectivity challenges for students in a Ghanaian university. *Portal: Libraries and the Academy*, 25(1), 55-65.
15. Kayi, E. A., & Van Wyk, M. M. (2025). Exploring Ghanaian distance learners' views of self-regulated learning strategies and academic performance. *Open Praxis*, 17(2), 376-393. <https://doi.org/10.55982/openpraxis.17.2.783>
16. Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.
17. Moustakas, C. (1994). *Phenomenological research methods*. SAGE Publications.
18. National Council for Curriculum and Assessment (NaCCA). (2023). *Mathematics common core programme (CCP)*. NaCCA.
19. National Council for Curriculum and Assessment. (2024). *Mathematics curriculum for secondary education (SHS I)*. NaCCA.
20. Österholm, E., Iiskala, T., Mustonen, R., & Murtonen, M. (2025). Metacognitive regulation: emergence, focus, and function in interprofessional collaborative learning. *Advances in Health Sciences Education*, 31, 1-20. <https://doi.org/10.1007/s10459-025-10458-z>
21. Polya, G. (1973). *How to solve it: A new aspect of mathematical method (2nd ed.)*. Princeton University Press. Sarpong, R. A. (2023, November). *Digitalisation of education in Ghana: An overview*. WATHI. <https://www.wathi.org/situation-education-ghana-2024/digitalisation-of-education-in-ghana-an-overview-november-2023/>
22. Schoenfeld, A. H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Journal of Education*, 196(2), 1-38. <https://doi.org/10.1177/002205741619600202>
23. Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science*, 26(1/2), 113-125. <https://doi.org/10.1023/A:1003044231033>
24. Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary educational psychology*, 19(4), 460-475. <https://doi.org/10.1006/ceps.1994.1033>
25. Supratman., Budayasa, I. K., & Rahaju, E. B. (2025). Probabilistic thinking process in probability problem-solving prospective mathematics teacher with field independent based on Polya's three stages. *Educational Process: International Journal*, 17, e2025333. <https://doi.org/10.22521/edupij.2025.17.333>
26. Sweller, J., Van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational psychology review*, 31(2), 261-292. <https://doi.org/10.1007/s10648-019-09465-5>
27. Toikka, S., Eronen, L., Atjonen, P., & Havu-Nuutinen, S. (2024). Combined conceptualisations of metacognitive knowledge to understand students' mathematical problem-solving. *Cogent Education*, 11(1), 2357901. <https://doi.org/10.1080/2331186X.2024.2357901>
28. van Manen, M. (2016). *Researching lived experience: Human science for an action sensitive pedagogy* (2nd ed.). Routledge.
29. Veenman, M.V.J., Van Hout-Wolters, B.H.A.M. & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition Learning*, 1, 3-14. <https://doi.org/10.1007/s11409-006-6893-0>
30. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press
31. Zhao, Y. & Saleh, S. (2025). Metacognition and mathematical problem-solving: An empirical investigation into series problems with junior high school students. *Mathematics Education Journal*, 9(1), 90-101. <https://doi.org/10.22219/mej.v9i1.39924>
32. Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice*, 41(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2