Latent Class Analysis of Mathematics/Science Students' Metacognitive Learning Strategies in College

Eliot Kosi Kumassah[1], Maxwell Seyram Kumah[2], & Ambrose Ayikue[3]

Abstract

Metacognitive learning refers to the process of being aware of and taking control of one's own learning. The effective use of metacognitive learning strategies (MLS) can lead to improved student learning outcomes. It helps student to set SMART goal, monitor their own progress, encouraging students to reflect on their own learning and providing feedback that is specific, constructive, and timely can help students to identify areas where they need to improve. The study focused on mathematics/science student's metacognition utilization in Colleges of Education in Volta region of Ghana. Of 323 population, 139 were sampled for the study using quantitative exploratory cross – sectional survey design. Twenty – five question items using Metacognitive Learning Utilization Questionnaire (M-LUQ) relating to planning, monitoring, evaluation, self-regulation and comprehension was used for data collection. The latent class analysis (LCA) suggests the three-class solution as the accepted best fitting model, based on statistical fit indicators AIC, BIC, entropy, Gsq, and Chsq. The result revealed that comprehension, monitoring and evaluation were very good, and averagely good respectively utilised by majority while self – regulation and planning were satisfactorily and poorly utilised by students. The variables were tested using one way ANOVA with high, moderate and low-level utilization. There was a statistically significant difference between all three-class based on the mean. The study indicate that comprehension was highly utilized while planning was the lowest utilized component (MLS). Is therefore, recommended student should be supported with metacognitive learning awareness with focus on planning and self-regulation. Other implications of the findings are discussed.

Keywords: metacognitive learning strategies; latent class analysis; students' learning outcomes

Introduction

Metacognitive learning strategies have been extensively studied in the field of mathematics and science education. Mathematics and science are considered challenging subjects that require a high level of cognitive effort and problem-solving skills. Hence, students need to develop metacognitive learning strategies to be successful in these subjects. In the field of mathematics and science education, metacognition has been identified as an essential factor for success. These subjects are often challenging, and require high levels of problem-solving and analytical skills. Students who lack metacognitive awareness may struggle to understand mathematical and scientific concepts, and may not be able to apply them effectively to solve problems.

Metacognition has been defined as the process of thinking about one's own thinking, and it involves the ability to monitor and regulate one's own cognitive

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processes (Gatcho & Hajan, 2019). It is a critical component of learning and academic success, as it enables students to understand their own cognitive strengths and weaknesses, and to develop effective learning strategies. Metacognition is also referred to an individual's ability to understand their own cognitive processes, monitor them during learning, and control and adjust them as needed. There are various classifications of metacognitive strategies, depending on the adopted definitions and the different associations and connotations within various research domains (Mitsea & Drigas, 2019). They stated that metacognition is divided into two main and interconnected components: metacognitive knowledge and metacognitive regulation with sub-components

A study revealed that students who use metacognitive strategies tend to have a deeper understanding of mathematical and scientific concepts, better problem-solving skills, and increased motivation to learn (Bahri & Corebima, 2015). In particular, metacognitive strategies such as planning, monitoring, and evaluating are essential for success in mathematics and science education. For instance, students who plan their problem-solving strategies before attempting a problem tend to perform better than those who do not (Cook, et al., 2013). Similarly, students who monitor their progress while solving problems tend to identify their mistakes quickly and correct them (Driscoll, et al., 2005). Aghaie and Zhang, (2012), has also shown that metacognitive learning strategies can be taught explicitly to students. Teachers can help students develop metacognitive strategies by modeling the use of these strategies and by providing explicit instruction on how to use them. They continue to opined that student who receive explicit instruction on metacognitive strategies tend to perform better on mathematical and scientific tasks than those who do not.

It was also identified that several metacognitive strategies that are particularly useful for mathematics and science students. These strategies include planning, monitoring, and evaluating (Muteti, et al., 2021). Planning involves setting goals, identifying resources, and developing strategies for achieving those goals. In the context of mathematics and science education, this might involve breaking down complex problems into smaller, more manageable steps, and identifying the appropriate tools and techniques to solve each step.

Metacognitive learning strategies are crucial for success in mathematics and science education. Students who use these strategies tend to have a deeper understanding of concepts, better problem-solving skills, and increased motivation to learn and also to monitor and regulate their own cognitive processes, in order to develop effective learning strategies. Teachers can play a vital role in helping students develop metacognitive strategies by modeling the use of these strategies and providing explicit instruction on how to use them. Despite significant research efforts on metacognition and its learning strategies, there is still confusion and fundamental questions regarding their precise structure, their functions in gaining self-knowledge in learning, and their relationship with the notion of consciousness.

Justification of the study and objectives

The study on assessing Mathematics/Science Students Metacognitive Learning Strategies in College of Education in Volta region, Ghana is justified for several reasons. Firstly, metacognition is recognized as a crucial component in successful learning, particularly in complex subjects such as mathematics and science. Therefore, understanding the metacognitive learning strategies used by mathematics/science students in College of Education in Volta region, Ghana is important in identifying the factors that influence their academic performance. Secondly, the assessment of metacognitive learning strategies is important for developing effective instructional strategies that promote learning and improve academic performance. By understanding the metacognitive learning strategies used by students, teachers can design teaching methods and activities that encourage students to plan, monitor, and evaluate their own learning. Thirdly, this study is justified in the context of the Ghanaian educational system, where there is a need to improve the quality of mathematics and science education at all levels. By identifying the metacognitive learning strategies used by students, this study can provide valuable insights for educational policymakers and practitioners on how to improve mathematics and science education in the country.

The following objectives were formulated to achieve the aims of study:

i. determine the classes of metacognitive learning strategies among mathematics/science students based on their high, moderate and low levels of cognitions.
ii. assess the mean differences in high, moderate and low levels of cognitions among mathematics/science students belonging to different latent classes of metacognition learning strategies.

Empirical Studies

Muteti, et al., (2021) studied about the students' metacognition learning in science (chemistry). The study stated that moving from high school to college can be challenging for many students, especially those in science, technology, engineering, and mathematics (STEM) programs who are required to take general chemistry courses. They indicated that many first-year students struggle to pass these courses due to ineffective study strategies that rely on rote memorization. Therefore, to assist students succeed in STEM programs, it is important for teachers to employ the metacognitive strategies in their academic careers. They argued that, though some studies have explored study strategies and the impact of metacognition on student performance in chemistry, there is a lack of qualitative research on the explicit teaching of metacognition and its influence on student study strategies. The study, used open-ended questionnaires to investigate general chemistry students' study strategies before and after a 50-minute metacognition lesson and how the instruction affected their performance on the final exam. Results showed that students relied more on rote memorization before the metacognition lesson, but reported gaining more higher-order study strategies afterward. Additionally, 67% of students reported a positive influence of the metacognition instruction on their study strategies, and those who reported such an influence had 7% lower DFs in the final exam compared to those who did not. The findings suggest the need to explicitly teach metacognitive strategies to students in general chemistry courses, as many students may not be aware of effective study strategies.

Noushad, (2008) suggests that teaching metacognitive strategies directly, such as in "learning to learn" courses, can improve learning outcomes. However, the independent use of these strategies takes time to develop. While there is much research to support this idea, it's important not to overlook the role that a student's experiences outside of the classroom play in the development of metacognitive skills. When students are in new social contexts and cultures, they naturally develop a metacognitive environment, which encourages "thinking about thinking" and problem-solving. This experience is crucial in preparing students for lifelong learning and adapting to new situations, which is essential in our rapidly changing world. As

Socrates suggested, examining everyday life in a new environment promotes the development of metacognitive skills that are necessary for a successful career. Therefore, teachers should prioritize teaching metacognitive strategies to equip students for the demands of the 21st century.

Mitsea and Drigas, (2019) also studied on the exceptional academic performance of East Asian students on global assessments has sparked debates about their learning behavior. The used a comparative analysis by conducting latent class analysis to examine the perceptions and reported use of learning strategies by Taiwanese and American students who participated in the Program for International Student Assessment (PISA) in 2012. The study also explored the relationships between learning strategies and self-efficacy. The findings of the study suggest that there were no significant differences in the perception of learning strategy items between Taiwanese and American students. However, Taiwanese students (5%) reported less memorization as a learning strategy than American students (19%). In contrast, more Taiwanese students (63%) reported using the elaboration strategy, while more American students (57%) reported using the control strategy. The study also found that Taiwanese students with high self-efficacy reported using memorization the least, whereas American students with high self-efficacy reported using elaboration less frequently than the control strategy. The implications of these findings are discussed in the study.

Lee, et al., (2014) focused on the impact of a metacognitive-based scheme on students' problem-solving abilities. According to the findings, the use of this scheme had a positive impact on several aspects of the students' problem-solving process. This suggest that metacognitive based learning improved their understanding of the problem at hand, which is a crucial aspect of problem-solving. The scheme also helped the students in planning their solutions effectively, suggesting that they were able to identify the steps necessary to solve the problem and develop a plan of action. Moreover, the scheme improved the students' confidence in their problem-solving abilities and their personal control over their emotions during the problem-solving process. This suggests that the students felt more in control of their emotions and less anxious or frustrated when working through the problem. The scheme also helped the students to initiate and persevere through the problem-solving process, which suggests that they were more motivated and less likely to give up when faced with obstacles. The use of the metacognitive-based scheme was linked to higher levels of problem-solving success. This indicates that the scheme was effective in improving the students' overall problem-solving abilities and helping them to achieve better results.

Similarly, Wang, (2019) suggests that providing metacognitive strategy instruction to students positively affects their ability to design programs. Additionally, the instruction helps in developing their planning, monitoring, and evaluating abilities, which ultimately contributes to making them independent and self-directed learners. The study highlights the importance of metacognitive strategies, metacognitive knowledge, and learning strategies in improving program design proficiency. Overall, the research implies that incorporating metacognitive strategy instruction in teaching can enhance students' learning outcomes and skills.

Contrarily, the finding of another study suggests that while students have learned the concept of metacognition, they are facing difficulties applying it to solve problems. Specifically, students struggle with the metacognitive skill of planning, as they find it challenging to set goals and prioritize their learning activities (Ristanto, et al., 2019). This could indicate a lack of proficiency in using metacognitive strategies to regulate their learning processes effectively. It is important to note that the ability to plan effectively is a critical aspect of metacognition, as it helps learners set clear objectives and develop strategies to achieve them. Therefore, this finding highlights the need for further interventions and support to help students develop their metacognitive skills, particularly in the area of planning, to enhance their learning outcomes.

In like manner, the results revealed that there was a lack of correlation among planning strategies and other variables such as cognitive abilities, academic performance, and research activity (Chuvgunova & Kostromina, 2016). This indicates that students' planning skills were insufficient and may have negatively affected their academic and research outcomes. The lack of correlation could imply that students who perform well academically and in research activities may not necessarily possess strong planning skills, which is a crucial aspect of metacognitive abilities. This finding emphasizes the need for interventions to improve students' planning skills and develop their metacognitive abilities, particularly in the context of academic and research activities. Improving planning skills and other metacognitive abilities can help students become more effective learners and achieve better academic and research outcomes.

The study titled "Multiple levels of metacognition and their elicitation through complex problem-solving tasks" showed that there is an opportunity to use a new understanding of metacognition to develop effective instructional methods and metacognitive activities. These interventions can be integrated into existing curricula to facilitate active and higher-order learning among students (Kim, 2013). This finding suggests that by re-conceptualizing metacognition and incorporating it into teaching and learning practices, educators can help students become more aware of their thinking processes and develop the skills needed to regulate their own learning. By doing so, students may engage more effectively in complex problem-solving tasks and other higher-order thinking activities, leading to better learning outcomes.

Hutajulu and Wahyudin, (2018) found that when senior high school students used metacognitive learning strategies, they achieved better results and showed improvement in their mathematical analysis abilities, as compared to those who used traditional learning methods. This suggests that metacognitive learning can be an effective alternative to traditional mathematics learning, and has the potential to enhance students' ability to analyze mathematical problems. By using metacognitive strategies, such as planning, monitoring, evaluating, and self-regulating their learning, students can become more aware of their own cognitive processes, which in turn can lead to better problem-solving skills and a deeper understanding of mathematical concepts. These findings highlight the potential benefits of incorporating metacognitive strategies into mathematics education, and suggest that educators may want to consider adopting these strategies to enhance students' learning outcomes.

The result of (Schneider and Artelt, 2010; Yang and Bai, 2019) also suggests that there have been several intervention studies that have shown that both average and low-performing learners benefit significantly from metacognitive instruction procedures. This indicates that metacognitive strategies can be effective for a wide range of learners, regardless of their current level of mathematics performance. These studies have demonstrated that metacognitive strategies, such as planning, monitoring, and evaluating, can help students become more aware of their own cognitive processes and improve their problem-solving skills, leading to better mathematical performance overall. Therefore, the use of metacognitive instruction procedures can be a useful tool for educators to help students with diverse learning abilities to enhance their mathematics performance.

The Study Framework of Metacognition

Metacognitive learning strategies involve a range of cognitive processes that enable individuals to become more aware of their own learning and thinking processes. Here are the main components of metacognitive learning strategies:

Planning: This involves setting goals, creating a plan of action, and identifying the steps needed to achieve those goals. *Monitoring*: This involves checking one's progress towards their goals, assessing their level of understanding, and recognizing when they need to adjust their learning approach. *Evaluating:* This involves assessing the effectiveness of one's learning strategies and reflecting on what worked and what didn't work. This helps individuals adjust their approach to learning for future success. *Knowledge of cognition*: This refers to having an understanding of how one learns, including the ability to recognize one's strengths and weaknesses in learning, and knowing what strategies work best for different types of learning tasks. *Self-regulation***:** This refers to the ability to control one's own learning processes and emotions. This includes self-motivation, self-discipline, and the ability to stay focused and engaged in learning.

The study context of assessing the metacognition among mathematics/science students in a college of education in Ghana, would be approached by investigating five key components of metacognitive processes: planning, monitoring, evaluation, self-regulation, and comprehension.

Planning: The planning component of metacognition involves setting goals, developing strategies, and organizing resources to accomplish a task. In the context of this study where mathematics/science students were included, planning involves identifying the key concepts to be learned, setting goals for learning these concepts, and developing study strategies to achieve those goals. This study investigates how mathematics/science students in the college of education in Hohoe plan their learning, what strategies they use, and how effective those strategies are in achieving their learning goals.

Monitoring: The monitoring component of metacognition involves checking progress toward a goal, evaluating understanding, and making adjustments to strategies as needed. In the context of this study where mathematics/science students were included, monitoring involves checking understanding of mathematical/scientific concepts as they are learned, and adjusting study strategies to improve understanding. This study investigates how mathematics/science students in the college of education in Hohoe monitor their understanding of mathematical/scientific concepts, what strategies they use to check their understanding, and how effective those strategies are in improving their understanding.

*Evaluation***:** The evaluation component of metacognition involves assessing the quality of performance and outcomes, comparing performance to goals, and identifying strengths and weaknesses in learning. In the context of this study where mathematics/science students were included, evaluation involves assessing the quality of mathematical/scientific problem-solving, comparing performance to learning goals, and identifying areas of strength and weakness in learning. The study could investigate how mathematics/science students in the college of education in Hohoe evaluate their performance and outcomes, what criteria they use to assess quality, and how effective those criteria are in identifying areas for improvement.

*Self-regulation***:** The self-regulation component of metacognition involves managing emotions, motivation, and behavior in the service of learning. In the context of this study where mathematics/science students were included, self-regulation could involve managing anxiety and frustration during problem-solving, motivating oneself to persist in learning challenging concepts, and avoiding distractions that interfere with learning. The study could investigate how mathematics/science students in the college of education in Hohoe self-regulate during mathematical/scientific problem-solving, what strategies they use to manage emotions and motivation, and how effective those strategies are in promoting learning.

Comprehension: The comprehension component of metacognition involves understanding and making meaning of information, concepts, and ideas. In the context of this study where mathematics/science students were included, comprehension could involve understanding mathematical/scientific concepts, interpreting data and graphs, and making connections between concepts. The study could investigate how mathematics/science students in the college of education in Hohoe comprehend mathematical/scientific concepts, what strategies they use to understand and make meaning of information, and how effective those strategies are in promoting learning.

Investigating these five components of metacognition could provide valuable insights into the metacognitive processes and strategies that are relevant to mathematics/science learning in a college of education in Hohoe, Ghana. The findings could be used to inform the development of effective metacognitive interventions and support programs for mathematics/science students in the college of education, and to contribute to the broader literature on metacognition in mathematics/science education in Ghana.

Methods and Materials

The study draws on both positivism and interpretivism epistemological philosophies, utilizing a deductive approach. The research methodology is primarily quantitative and follows an exploratory cross -sectional survey research design. The exploratory cross – sectional survey research design was chosen for this study because it allows the researcher to gain a deeper understanding of the issue being studied without the expectation of producing conclusive outcomes. Exploratory research in itself is often used when the research problem or area of interest is not well defined or understood, or when there is little existing research on the topic.

In an exploratory research design, the focus is on gaining insights, generating hypotheses, and exploring potential relationships between variables. The goal is to gather as much information as possible to help inform future research and guide the development of research questions and hypotheses. One of the benefits of an exploratory research design is that it allows for flexibility and adaptability. If new data or ideas emerge during the exploration, the researcher(s) must be open to changing course and adjusting their methods or questions accordingly. This flexibility can lead to unexpected insights and new directions for research that might not have been considered otherwise.

The population of the study was made up of 323 mathematics/science students from two public colleges of education in Volta region, Ghana with accredited undergraduate programs. The participating colleges were masked for security and confidentiality reasons. The population of the study was distributed as follows: College A (N=162) and College B (N=161). The purposive and simple random sampling technique was used to select a sample of 139 level 300 mathematics/science students as respondents for the study. This sample represents 43.03% of the study's population and is distributed as follows: College A (n=69), College B (n=70). Data collection was done using an instrument called the "Metacognitive Learning Utilization Questionnaire (MLUQ)" designed by the researcher. The questionnaire was structured into five sections – A, B, C, D and E. Section A was designed to collect data on student planning, section B was used to collect information on the student monitoring nature of their own work. Section C was used to collect information on student evaluation of their learning. Sections D and E were used to collect data on student self – regulation and comprehension their learning. All twenty – five (25) question items of the questionnaire were organized on a five-point Likert scale, ranging from strongly agree to strongly disagree in some cases, very confident to not confident in another case and very well to not very well in another case. Each section has five question items.

The instrument was validated by three experts (one mathematician, scientist and a guidance and counsellor) from both participating colleges. The Cronbach alpha approach was used to establish the instrument's reliability after a trial test had been conducted on 20 mathematics/science students from one of the participating colleges but were not part of the main study but were drawn from the study's population. permission was obtained from the colleges Professional Development and Research Committee before conducting the research. The researchers explained the study's objectives and the respondents' role expectation before administering the questionnaire. Participation in the study was voluntary, and data collected would be used only for research and publication purposes. Responses to sections A, B, C, D and E of the survey would be aggregated, and statistical analysis results would be published in a peer-reviewed journal. After these explanations, the researchers administered copies of the instrument to 146 participants who consented to participate through the support of two research assistants. However, the researcher recovered 139 copies of the instrument administered, indicating a return rate of 95.2% of the instrument's copies administered and a shortage of 4.8% from the original sample. The collected data were sorted, scored, and coded accordingly. The researcher transformed the data by grouping all responses indicating high, moderate and low level utilizing metacognitive learning strategy across all items in sections A, B, C, D and E of the instrument into group 1, 2 and 3 respectively. In the latent class analysis (LCA), when indicator variables have fewer levels, it is simpler to evaluate the class solution when several answer alternatives are collapsed into two or three options (Weller et al., 2020; Owan, et al., 2022).

Results and Findings

Latent class analysis (LCA) is a statistical technique used to identify latent or unobserved subgroups within a population based on observed categorical data. LCA assumes that the observed data arise from a finite number of unobserved classes, and each individual belongs to one of these classes. To fit the LCA model, the following steps are typically followed:

1. Data preparation: This involves selecting the variables that were used in the analysis and recoding them into categorical variables.

2. Determine the number of latent classes: The number of latent classes in the data was determined. This was done using various statistical criteria such as the AIC, BIC, entropy, or likelihood ratio tests. As different criteria may suggest different numbers of classes, it was important

to consider multiple criteria and use expert judgment.

3. Model estimation: This is done using maximum likelihood estimation or Bayesian methods. The output of this includes the estimated probabilities of each individual belonging to each latent class and the estimated probabilities of each category within each variable given each latent class.

4. Model evaluation: This was done using various fit indices; AIC, BIC, entropy, G^2, or χ^2. It is also important to examine the distribution of individuals across the latent classes and the estimated probabilities of each category within each variable given each latent class to ensure that the classes are meaningful and interpretable.

5. Interpretation: This involves identifying the latent classes and describing their characteristics based on the estimated probabilities of each category within each variable given each latent class. It is also important to examine the relationships between the latent classes and other variables in the dataset.

Table 1 shows the results of fitting two different models to some data, where each row corresponds to a different model with a different number of parameters. The models were evaluated based on several criteria: AIC, BIC, entropy, G^2, and χ^2. Here is what each of these measures means: AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) are measures of the relative quality of statistical models for a given set of data. Both criteria penalize models that have more parameters, but BIC penalizes complex models more heavily than AIC. In general, lower AIC and BIC values indicate better model fit. Entropy is a measure of the uncertainty or disorder in a system. In the context of model selection, it can be used to evaluate the degree of separation between different groups or clusters of data points. Higher entropy values indicate less separation between clusters. G^2 (deviance) and χ^2 (chi-squared) are measures of the goodness of fit of a statistical model to a set of data. They are calculated as the difference between the observed data and the expected data under the model, divided by the expected data. In general, lower G^2 and χ^2 values indicate better model fit. From Table 1, it is observed that the model with 3 parameters has lower AIC and BIC values than the model with 2 parameters, indicating better model fit. The entropy value for the model with 3 parameters is also slightly higher, indicating slightly less separation between clusters. However, the G^2 and χ^2 values for the model with 2 parameters are lower than those for the model with 3 parameters, suggesting better goodness of fit.

Table 1 Model fit measures

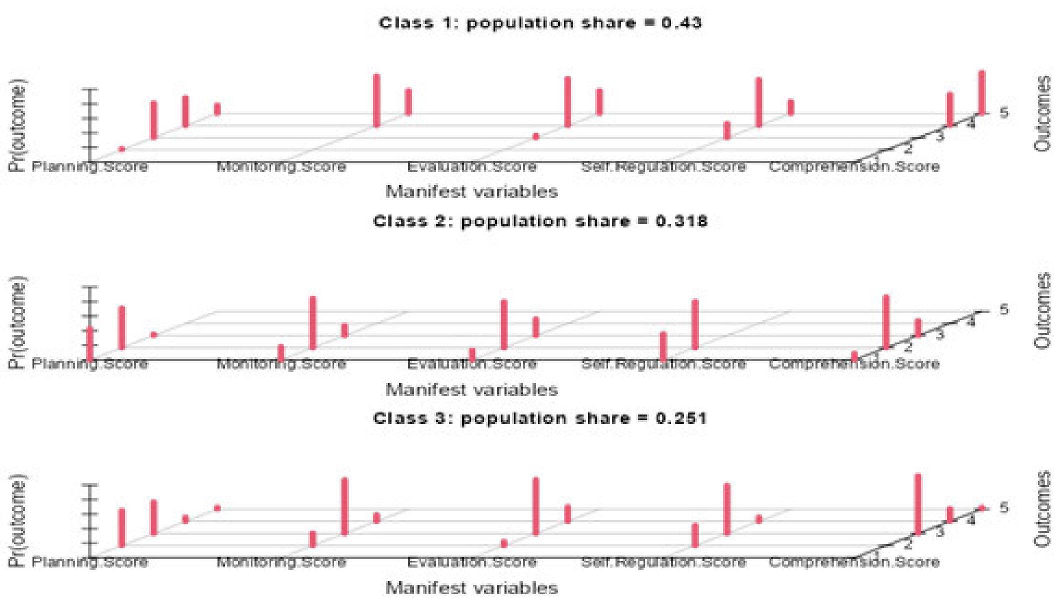
Class	AIC	BIC	Entropy	G^2	χ^2
2	1627	1747	0.97	524	6287
3	1510	1692	0.961	365	1253
4*	1470	1713	0.967	283	804
5*	1461	1766	0.976	231	528

*Excluded from the model

Figure 1 showed the LCA plot manifesting variables with three class membership. The estimated class probabilities provide information on the prevalence of each latent class. In this case, the estimated class probabilities are: Class 1 (high) = 0.43, Class 2 (moderate) = 0.318, Class 3 (low) = 0.251. This means that in the sample of individuals analyzed, about 43% of them are estimated to belong to the high meta-cognitive level class, 31.8% to the moderate level class, and 25.1% to the low-level class.

moderate planning group were more evenly distributed across categories, with similar proportions reporting either poor, satisfactory, or averagely good planning abilities. The low planning group had a relatively high proportion reporting poor planning abilities, with smaller proportions reporting satisfactory, averagely good, or good abilities. This suggest that students who are classified as having high planning abilities may be better equipped to manage their time and prioritize their tasks in

Figure 1 LCA plot manifesting variables with three-class membership



What are the classes of metacognitive learning strategies among mathematics/science students based on their high, moderate and low levels of cognitions? (RQ1)

Table 2 shows the estimated probabilities of each category within each variable given each level of the corresponding factor. For example, (1) with the planning variable, the majority of individuals in the high planning group reported either averagely good or good planning abilities, with smaller proportions reporting either satisfactory or very good abilities. In contrast, those in the

academic learning environments. This could lead to more efficient use of their time and better performance in their coursework. However, students who are classified as having low planning abilities may struggle with time management and task prioritization, which could lead to procrastination and poorer academic performance. (2) with the monitoring variable, individuals in the high monitoring group had a high probability of reporting averagely good monitoring abilities, with a smaller proportion reporting very good ability. In contrast, those in the low monitoring group were more likely to report satisfactory or good abilities, with smaller proportions reporting averagely good or very good abilities. The findings indicate that students who are classified as having high monitoring abilities may be better at tracking their progress and identifying areas where they need to improve. This could help them to take corrective action early and improve their academic performance. On the other hand, students who are classified as having low monitoring abilities may struggle to identify their weaknesses and may require additional support to improve. (3) with the evaluation variable, the high evaluation group had a high probability of reporting either averagely good or good evaluation abilities, with a smaller proportion reporting satisfactory abilities. The low evaluation group had a relatively high proportion reporting either good or very good abilities, with smaller proportions reporting satisfactory or averagely good abilities. It implies that students who are classified as having high evaluation abilities may be better at assessing their own work and identifying areas where they need to improve. This could lead to more effective self-directed learning and better academic performance. However, students who are classified as having low evaluation abilities may struggle to assess their own work and may require additional feedback and guidance from their teachers. (4) self-regulation variable, individuals in the high self-regulation group had a high probability of reporting either averagely good or good self-regulation abilities, with a smaller proportion reporting satisfactory abilities. The low self-regulation group had a relatively high proportion reporting either satisfactory or averagely good abilities, with a smaller proportion reporting good abilities. It may mean that students who are classified as having high self-regulation abilities may be better at managing their own learning and staying motivated in virtual learning environments. This could lead to better academic performance and greater success in their coursework. However, students who are classified as having low self-regulation abilities may struggle with self-directed learning and may require additional support and guidance from their teachers. (5) comprehension variable, individuals in the high comprehension group had a high probability of reporting either good or very good comprehension abilities, with a smaller proportion reporting averagely good ability. The low comprehension group had a relatively high proportion reporting Satisfactory comprehension abilities, with smaller proportions reporting averagely good, good, or very good abilities. Students who are classified as having high comprehension abilities may be better at understanding and retaining the material presented in virtual learning environments. This could lead to better academic performance and greater success in their coursework. However, students who are classified as having low comprehension abilities may struggle to understand the material and may require additional support and guidance from their teachers.

What are the mean differences in high, moderate and low levels among mathematics/science students belonging to different latent classes of metacognition learning strategies? (RQ2)

Table 3 showed the descriptive statistics of the three categories of students' (high, moderate, and low) rating of the student categories' rating of their levels of meta-cognitive learning on the metacognitive learning strategies.

Table 3 Descriptive statistics of the student categories' rating of their levels of meta-cognitive learning on the metacognitive learning strategies

Metacognition learning strategies	Categories of students by meta-cognitive learning levels					
	High level (N=60)		Moderate level (N=47)		Low level (N=32)	
	Mean	SD	Mean	SD	Mean	SD
Planning	3.60	0.718	1.62	0.534	2.69	0.738
Monitoring	4.32	0.469	1.96	0.550	3.00	0.440
Evaluation	4.28	0.524	2.15	0.625	3.16	0.515
Self-Regulation	3.97	0.610	1.66	0.479	2.84	0.515
Comprehension	4.57	0.500	2.17	0.564	3.25	0.508

The students with high levels of meta-cognitive ability scored higher on all five strategies compared to students with moderate and low levels of ability. Students with moderate levels of ability had lowest scores on all five strategies, and those with low levels of ability had the intermediate scores. Specifically, students with high levels of meta-cognitive ability had a mean score of 3.60 (SD=0.718) on planning, while students with moderate and low levels of ability had mean scores of 1.62 (SD=0.534) and 2.69 (SD=0.738), respectively. Similarly, students with high levels of ability had mean scores of 4.32 (SD=0.469) on monitoring, 4.28 (SD=0.524) on evaluation, 3.97 (SD=0.610) on self-regulation, and 4.57 (SD=0.500) on comprehension, while students with moderate and low levels of ability had lower mean scores on all five strategies. These results suggest that students with higher levels of meta-cognitive ability tend to use a wider range of meta-cognitive learning strategies more effectively compared to students with lower levels of ability. This information could be used to develop interventions to improve meta-cognitive learning skills among students with lower levels of ability.

Based on the mean scores in the Table 3, it appears that students with high levels of meta-cognitive ability tend to utilize all five meta-cognitive strategies more than students with moderate and low levels of ability. However, it's worth noting that among students with all levels of ability, the mean score on comprehension is the highest, followed by monitoring, evaluation, self-regulation, and planning. Therefore, it seems that comprehension is the most utilized meta-cognitive strategy by students, while planning is the least utilized strategy.

Table 4 showed the results of statistical tests for the differences in means between the three levels of meta-cognitive ability (high, moderate, and low) for each of the five meta-cognitive strategies (planning, monitoring,

Table 4 One-Way ANOVA (Fisher's) results of metacognition assessment of mathematics/science students

	F	df1	df2	P
Planning	117	2	136	< .001
Monitoring	307	2	136	< .001
Evaluation	194	2	136	< .001
Self-Regulation	235	2	136	< .001
Comprehension	279	2	136	< .001

evaluation, self-regulation, and comprehension). For each strategy, the Table 4 shows the F-statistic (corresponding to an ANOVA test) with its associated degrees of freedom (df1 and df2) and p-value. The p-values for all strategies are less than .001, which indicates that there are significant differences in the means of the three levels of ability for each strategy. Therefore, we can conclude that there are statistically significant differences in the use of all five meta-cognitive strategies among students with different levels of ability.

Table 5 shows the mean differences (MD) and associated p-values for pairwise comparisons between different classes (I and J) for each meta-cognitive strategy. The p-value indicates whether the mean difference is statistically significant or not. For each meta-cognitive strategy, there are three comparisons: High vs. Moderate, High vs. Low, and Moderate vs. Low. The MD indicates the difference in mean score between the two classes being compared. Based on the MD values and p-values, we can see that for all meta-cognitive strategies, the High class has significantly higher mean scores than the Moderate and Low classes. The Moderate class also has significantly higher mean scores than the Low class for all strategies. Therefore, we can conclude that students in the High class tend to utilize meta-cognitive strategies more effectively than those in the Moderate and Low classes, and students in the Moderate class tend to utilize these strategies more effectively than those in the Low class.

Table 5 **Tukey Post-Hoc test of metacognition assessment of mathematics/science students**

	Class (I)	Class (J)	MD	p
Planning	High	Moderate	1.98	<0.001
	High	Low	0.913	<0.001
	Moderate	Low	-1.07	<0.001
Monitoring	High	Moderate	2.36	<0.001
	High	Low	1.32	<0.001
	Moderate	Low	-1.04	<0.001
Evaluation	High	Moderate	2.13	<0.001
	High	Low	1.13	<0.001
	Moderate	Low	-1.01	<0.001
Self-regulation	High	Moderate	2.31	<0.001
	High	Low	1.12	<0.001
	Moderate	Low	-1.18	<0.001
Comprehension	High	Moderate	2.4	<0.001
	High	Low	1.32	<0.001
	Moderate	Low	-1.08	<0.001

Discussion

From the results regarding the utilization of metacognitive learning strategy, it seems that the mathematics/science students have a relatively good level of utilization of metacognitive learning strategies, particularly in the components of planning, monitoring, evaluation, and comprehension. These categories show relatively high ratings in the levels of averagely good, good, and very good, particularly in the high and moderate categories. Self-regulation, on the other hand, shows relatively lower ratings across all levels of quality, particularly in the moderate and low categories. These results suggests that mathematics/science students are generally utilizing metacognitive learning strategies, but may need more support and guidance in the area of self-regulation. The study also indicate that the participants made use of comprehension and monitoring during learning but struggle to plan and self-regulate their learning.

Several studies on metacognitive learning intervention found similar outcome of this study in the report. For example, Schneider and Artelt, (2010) indicate that the use of metacognitive instruction procedures has been found to be an effective approach for improving mathematics performance among a broad range of learners, including those who may struggle with mathematics. This suggests that the use of metacognitive instruction procedures may have a valuable role to play in mathematics education and may help to improve learners' confidence and engagement with mathematics. similarly, another study argued that re-conceptualization of metacognition has the potential to guide the development of effective instructional methods and activities that can help to engage learners in active, higher-order learning. Such methods and activities may include strategies for goal-setting, self-monitoring, reflection, and self-evaluation, which can help learners to become more aware of their own learning processes and develop effective learning strategies (Kim, et al., 2013). The study suggests that the integration of metacognitive activities and effective instructional methods into existing curricula is necessary to engage learners in active, higher-order learning. This integration may involve the development of new instructional materials, or the modification of existing materials to incorporate metacognitive activities and strategies. It implies use of metacognition has the potential to inform and guide the development of effective instructional practices that can help to engage learners in active, higher-order learning and improve learning outcomes. Also Yang and Bai, (2019) considered three components of the metacognitive for PhD students and revealed that students are likely create a plan for their research project, outlining the steps they would take and the resources they would use to complete their project in time; student are likely to monitor their progress as they worked on their research project, making changes to their plan as needed and are likely to evaluate their research project upon completion, identifying what worked well and what could be improved for future projects. This suggests that the students in the study were actively engaged in their own learning process and used metacognitive strategies to improve their efficiency and research competence.

Conclusion and recommendation

This study based on the on the findings conclude that mathematics/ science student in colleges of education, Volta region, Ghana has averagely moderate use of metacognitive learning strategy, precisely in planning, monitoring, evaluation and comprehension but not self-regulation. The LCA model used in this study predict that the mathematics/science student demonstrate high level of comprehension, monitoring and evaluation respectively, and low level of self-regulation and planning. In view of these it is recommended that;

1. The colleges of education management should create a metacognitive learning awareness among all student teachers to improve the learning strategies
2. Student as adult learners should take self – responsibility of learning styles that suit them.
3. Student should pay conscious attention to their learning plan and self-regulation
4. None scoring self-development, guidance and psychology course should be mandatorily mounted for students to take at their own pace. This will help them overcome

planning and self-regulation deficiency.

Limitation and Suggestion for Future Studies

The study was encountered the following limitation:

There was difficulty in retrieving the distributed questionnaire but was overcome by extending the allocated time and consistent visitation and giving remainder notice to participants. The methodology employed in classifying the metacognitive student using LCA is novel in the study area and so other interest researchers should embark on similarly survey. This will reveal deep understanding of the classification of the various metacognitive component of learning.

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