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Latent Class Analysis of Learning Strategies and Metacognition: Their Effects on Mathematics Performance

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Abstract

This paper aimed to determine the latent classes of learning strategies and metacognition and their effects on the mathematics performance of selected senior high school students in the Philippines. A total of 1,313 students was selected using multi-stage cluster sampling. A modified questionnaire was used to collect data. Results revealed that a five-class model was the optimal fit model for both learning strategies and metacognition. ANOVA test results revealed that there was a significant difference in the mathematics performance of the students, implying that different types of learning strategies affected student performance and that the "Control Strategies Group" performed most effectively compared to other groups. On the other hand, the metacognition approaches taken showed no significant differences. In addition, no significant interactions took place between learning strategies and metacognition. This means that the two variables behaved independently, and only the learning strategies affected respondents' mathematics performance.

Keywords: *Latent class analysis, learning strategies, metacognition*

Introduction

Mathematics is a very important part of academics, as well as in everyday life. Knowledge and skills in mathematics are necessary in the workplace and in everyday life to solve basic and complex problems. Recognizing this, learning mathematics becomes a major emphasis at all levels of an educational institution. In fact, in most countries, mathematics is being taught across primary and secondary levels. Thus, everybody is expected to be equipped with the needed mathematical skills and knowledge. However, it is alarming to know that mathematics literacy of students nowadays is quite low.

Based on the report of the Programme for International Students Assessment (PISA) prepared by the Organization for Economic Co-operation and Development (OECD, 2018), mathematical literacy is defined as the process of "formulation, employment, and interpretation of mathematics in a varied circumstance." It comprises thinking logically and using mathematical concepts and forecast phenomena. It measures the capability of individuals to recognize the role that is being played by mathematics in the world, and to make necessary decisions to be productive and yearning citizens. The PISA also was able to establish baseline proficiency level 2, on a 1–6 scale, at which individuals should be demonstrating this productive capacity as students, workers, and citizens. Based on the results of PISA 2015, in more than half of the participating countries from the middle and low-income class, the scores in mathematics obtained fell below level 2. This is an indication that the mathematics literacy of students is low.

An international assessment like PISA has given a result that is not different from mathematics literacy in the Philippines. The latest result of Trends in International Mathematics and Science Study (TIMSS; Fact Fish Research Made Simple! 2018) revealed that the mean performance of grade eight Filipino Students was 377.7, whereas the center of the data was 500. This result is quite alarming when compared to other countries in the world. Both the PISA and TIMSS results revealed that Filipino

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students are performing below average mathematical literacy. The Philippines joined the international TIMSS assessment in 2003. Thus, this is the last reference that can be used in terms of international assessments. PISA 2018 had not yet been released when this paper was written.

Learning strategies may be critical to the academic performance of students. In the process of learning mathematics, students acquire learning strategies from their teachers and peers in order to improve their learning efficiency. According to the OECD (OECD, 2017), students who have outstanding mathematics performance usually adopt their learning strategies appropriately to manage their learning. On the other hand, students who have poor mathematics performance cannot actually apply effective learning strategies to solve problems. Based on the study of Lin and Tai (2015), in mathematics learning, students learn more effectively by consciously adopting effective learning strategies than just following their teachers' instructions. Clearly, learning strategies are a factor to be considered in attaining higher mathematics performance.

Besides learning strategies, another factor to focus on that affects mathematics performance is students' metacognition. As mentioned by Jaafar and Ayub (2010), mathematics performance and metacognition of students are positively correlated. They concluded that students' metacognition was the principal predictor of academic achievement in mathematics. Therefore, mathematics educators should give attention to mathematics metacognition as an important variable in mathematics education.

The concept of metacognition is connected to the knowledge of "when and how" to use a particular strategy for the learning process or in problem solving (Metcalfe & Shimamura, 1994). Metacognition, as defined by Schoenfeld (1987), means *thinking about thinking*, and it encompasses three important features which are: knowledge about our own thought processes, control or self-regulation, and belief and intuition. Meanwhile, according to Ozsoy (2011), metacognitive strategy is defined as methods used to help the students understand how they learn. By using a metacognitive strategy, students will be able to develop suitable plans during the teaching and learning process either by memorizing or routine.

The purpose of this study was to determine the latent classes of learning strategies and metacognition and their effects on students' mathematics performance. Most students in elementary and high school have poor performances in mathematics. Helping both teachers and students improve their performance by seeking possible solutions was one of the aims of this study. Although few studies have been conducted about Latent Class Analysis (LCA) and its effect on mathematics performance, the emphasis of this paper was the interaction of learning strategies and metacognition after identifying the latent classes of the students. Also, this is the first time that the Philippines has offered classes at senior high school level; hence, this paper is a pioneer in terms of including senior high school students as respondents.

Methodology

The respondents of this study were 1,313 senior high school students in Region IV-A (CALABARZON). The samples were selected using multi-stage cluster sampling. A modified instrument was utilized in this study. It was composed of three major parts. The first part involved the demographic profile of the students. The second part consisted of a questionnaire for learning strategies, and the third part dealt with metacognition. The students chose among three given options for each learning strategy, and in metacognition, they selected the item that best described their preparation for a mathematics exam.

To determine the latent classes of the students' learning strategies and metacognition, LCA was used. According to Lin and Tai (2015), LCA is a multivariate method designed to identify unobserved (or latent) subpopulations of individuals on the basis of multiple measures. LCA is like cluster analysis applicable to latent variables or categorical variables only. In this study, the respondents were divided into different groups based on learning and metacognition strategies using conditional probabilities computed for each category. The subjects that were considered in each of the classes of learning strategies and metacognition were highly homogeneous, and the groups created were heterogeneous when compared with each other. The procedure was undertaken using Statistical Packages for Social Sciences (SPSS) and R studio software. These two packages were some of those available that included Latent Class Analysis.

To determine the best fit model, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used. The optimal fit model for learning strategies and metacognition was the class number with the lowest AIC and BIC values.

To determine the effects of learning strategies and metacognition on students' mathematics performance, Analysis of Variance (ANOVA) was used. To determine the interaction effect of learning strategies and metacognition on the performance of the students, Two-way ANOVA was used.

Results and Discussion

Table 1 shows the descriptive statistics relevant to students in General Mathematics taken during the first semester of Grade 11. The table also shows that the average grade of the 1,313 students was 86.86, with a standard deviation of 4.96. This implies that the majority of students were performing well in math, with a slight deviation from the average grade across all genders, strands, and types of school.

The same table shows the distribution of respondents according to grade interval. The figures imply that most students obtained a grade from 85–89, which corresponded to 41.10% of the total number of students. On the other hand, only a few obtained a grade between 90 and 100. Therefore, most performed well, but not very well, and there was still a significant number of students who performed low (between 75 and 79). Based on the description of grades of the Department of Education, most students performed very satisfactorily in math, while few did not meet expectations.

Learning Strategies Results

The results of LCA for learning strategies are presented in Table 2. It shows two criteria (AIC and BIC) for each class model. As previously presented, the lowest values for AIC and BIC give the optimal fit model for learning strategies. The results imply that the AIC and BIC are the smallest for the five-class model (14,783.33 and 15,114.90, respectively). Thus, the five-class model is a suitable model for students' learning strategies.

Table 1. Distribution of Respondents According to Grade Interval in General Mathematics

Grade Interval	Frequency	Percent
74 and below (Did not meet expectations)	5	0.4
75–79 (Fairly Satisfactory)	78	5.9
80–84 (Satisfactory)	277	21.1
85–89 (Very Satisfactory)	540	41.1
90–100 (Outstanding)	413	31.5
Total	**1313**	**100.0**
Mean	86.86	
Standard Deviation	4.96	

The results of LCA for metacognition are also presented in Table 2. The values were smallest for the five-class model (15,689.48 and 16,021.06, respectively). Thus, the five-class model is a suitable model for student metacognition. All 1,313 students were divided into five classes of metacognition.

Table 2. Summary of AIC and BIC Criteria by Class Model for Learning Strategies and Metacognition

Model	Learning Strategies		Metacognition	
	AIC	BIC	AIC	BIC
2-class	16,639.81	16,769.31	17,672.73	1,7802.23
3-class	16,185.26	16,382.10	16,996.28	1,7193.12
4-class	15,494.10	15,758.28	16,437.76	1,6701.94
5-class	14,783.33	15,114.90	15,689.48	1,6021.06

After finding the optimal fit class model for learning strategies, the next step in the process was to determine the class probabilities and label each class. The probabilities of the five-class model are shown in Table 3. For class 1, the class probability (last row) indicated that 25% of the students were thus classified. For the remaining classes 16% of the students were classified as Class 2, 13% classified as Class 3, 16% classified as Class 4, and 3% classified as Class 5.

Table 3 shows the conditional probability of students in each class for individual items and options. The conditional probability for Class 1 students was .53, implying that 53% of students in Class 1 chose "I try to figure out what are the most important points to learn." Similarly, the conditional probability for Class 1 students was .24, which also indicates that 24% of students under Class 1 chose "I learn as much as I can by heart." The probability values presented in each category for individual indicators were used to assign a label to each class. Based on the distribution of conditional probabilities presented in Table 3, students under Class 1 who prepared for a mathematics exam, study mathematics, and solve mathematics problems, tend to use "Control" as learning strategy, since this strategy obtained the highest probability for each category (A1 to A3).

Table 3. Conditional and Class Probabilities on Learning Strategy Scale for the 5-Class Model

Item Code	Statement	Strategy	Class 1	Class 2	Class 3	Class 4	Class 5
A1	I try to figure out what are the most important points to learn.	Control	.53	.30	.33	.32	.24
A2	I try to understand new concepts by relating them to things I already know.	Elaboration	.24	.40	.39	.40	.31
A3	I learn as much as I can by heart.	Memorization	.24	.29	.28	.22	.44
B1	I try to figure out which concepts I still do not understand completely.	Control	1.00	1.00	1.00	.00	.00
B2	I think of new ways to get an answer.	Elaboration	.00	.00	.00	.98	.00
B3	I make myself check to see if I remember the work I have already done.	Memorization	.00	.00	.00	.00	.00
C1	I try to relate the work to things I have learned in other subjects.	Control	1.00	.30	.73	.41	.29
C2	I start by working out exactly what I need to learn.	Elaboration	.00	.56	.00	.42	.39
C3	I go over some problems so often that I feel as if I could solve them in my sleep.	Memorization	.00	.13	.25	.15	.56
D1	I go through examples again and again in order to remember the methods for solving mathematics problems.	Control	1.00	.00	.00	.25	.18
D2	I think about how the mathematics I have learned cam be used in everyday life.	Elaboration	.00	.32	1.00	.58	.15
D3	I always search for more information to clarify the problem when I cannot understand something.	Memorization	.00	.67	.00	.17	.67
	Class Probability		**.25**	**.16**	**.13**	**.16**	**.03**

For items B1, B2, and B3 under Class 1, the highest probability approached a value of one corresponding to item B1. This means that essentially all the students chose the item “I try to figure out which concepts I still do not understand completely.” This item falls under the “Control Strategy.”

For items C1, C2, and C3, still under Class 1, the highest probability of one was obtained by C1. This implies that all the students chose the item “I try to relate the work to things I have learned in other subjects.” This item falls under the “Control Strategy” as well, and none of the students chose the other two options.

For the last items D1, D2, and D3 under Class 1, the highest probability of one was again obtained by D1. This means that all the students chose “I go through examples again and again in order to remember the methods for solving mathematics problems.” On the other hand, none of the students chose the other two options. D1 still falls under “Control Strategy.” Among all the indicators under Class 1, the highest probabilities were under “Control Strategy.” Thus, the students under Class 1 were labeled as the “Control Strategy” students.

For the Class 2 probability values, it can be noticed in Table 3 that the highest conditional probabilities for the different indicators were obtained by A2, B1, C2, and D3, with probabilities of .40, 1.00, .56, and .67 respectively. These probabilities were under “Elaboration,” “Control,” “Elaboration,” and “Memorization.” Thus, Class 2 was labeled as a “Multiple Strategies” group. The students under this class tended to use all the strategies when studying for mathematics exams and solving mathematical problems. Class 3 students show a preference for using “Control” and “Elaboration” strategies since these strategies obtained the highest conditional probability for all the categories. The items A2, B1, C1, and D2 obtained the highest probabilities of .39, 1.00, .73, and 1.00 respectively. Hence, Class 3 students were labeled the “Control and Elaboration” group.

Class 4 students tended to use the “Elaboration” strategy, since this obtained the highest conditional probability for all the categories and options. The items A2, B2, C2, and D2 obtained the highest probabilities of .40, .98, .42, and .58 respectively. These items were all under the “Elaboration Strategy” group. Thus, Class 4 was labeled the “Elaboration Strategy” group. The last class in the model, Class 5, tended to use the “Memorization” strategy. Since this category obtained the highest conditional probabilities, the items A3, C3, and D3 obtained the highest probabilities of .44, .56, and .58, respectively. These items were all under the “Memorization Strategy” group. As a result, “Class 5” was labeled as the “Memorization Strategy” group. The students under this class tended to use memorization in studying for mathematics exams and solving mathematical problems.

Table 4 shows descriptive statistics regarding students’ mathematics performance for the five classes of learning strategies.

Table 4. Mathematics Performance Descriptive Statistics for Five-Class Model of Learning Strategies

Class	**Type**	***N***	**Mean**	**Std. Deviation**
1	Control	326	87.58	4.61
2	Multiple Strategies	211	86.44	4.98
3	Control and Elaboration	171	86.55	5.00
4	Elaboration	209	86.61	5.40
5	Memorization	396	86.74	4.93
	Total	1313	86.86	4.96

ANOVA analysis indicated significant differences existed ($p < .046$). Thus, it can be concluded that learning strategies affected the mathematics performance of the selected respondents. Further analysis was performed using the Least Significant Difference (LSD) post hoc test (Table 5). It also showed that significant differences existed, as all the significance values were less than the 5% level.

Referring back to Table 4, the mean score of students for the five types of learning strategies showed that students in the Control Strategies group performed better; this was followed by the Memorization Strategies group. The students with the lowest mathematics performance were found in the Multiple Strategies group. These results contradict those of Lin and Tai (2015) in Taiwan. In their study, the multiple strategies group was found to be the most effective among all the learning strategies. Their control strategy group had the lowest performance. In can be noticed, however, that there are minimal differences in the performance between the groups in the present study, and the means differed only at around the 5% level.

On the basis of the present results, it is concluded that the control strategy was the most effective in achieving high performance in mathematics among the selected senior high school students. Control strategies are defined as determining what students have learned and what they are still needing to learn. On the other hand, students using multiple strategies tended to have low mathematics performance. This implies that using multiple strategies in learning mathematics is not as effective as using a single strategy–specifically, the control strategy.

Table 5. LSD Post Hoc Test on Mean Grade Differences between Classes

(I)Highest Probability Class			Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
LSD	Control	Multiple	1.13	0.44	.100	0.28	1.99
		Control and Elaboration	1.02*	0.47	.029	0.11	1.94
		Elaboration	0.96*	0.44	.028	0.10	1.82
		Memorization	0.83*	0.37	.025	0.11	1.56

* $p < .05$

Metacognition Results

The next part shows the results of the metacognition of the respondents selected for the study. The probability values of the five-class model are presented in Table 6. For students under Class 1, the mean class probability was .23, implying that 23% of the students were classified as Class 1 students. For Classes 2, 3, 4, and 5, the class probabilities are shown, indicating that 20% of the students were classified as Class 2 and also as Class 3, 24% were classified as Class 4, and 13% were classified as Class 5.

Table 6 shows the conditional probabilities of students in each class for individual items and options. The conditional probability for Class 1 students indicated that no student chose either the E1 or E3 options. On the other hand, there was a high probability (99%) of students choosing “I set specific goals before I begin a task.” This item falls under the “Task Strategy” heading.

The probability in each category for individual indicators was used to assign a label to each class. Based on the distribution of conditional probabilities presented in Table 6, students under Class 1 who prepared for the mathematics exam, studied, and solved mathematics problems tended to have knowledge of both “Person and Task,” since this strategy obtained the highest probability for each category. The items E2, F1, G1, and H2 obtained the highest probabilities. All these items are under “Task” and “Person” knowledge of metacognition. Thus, Class 1 was labeled the “Knowledge of Person and Task” group.

The students under Class 2 were inclined to have “Multiple” strategies when studying for a mathematics exam and in solving mathematics problems. All metacognitive strategies obtained the highest conditional probabilities, with items E3, F2, G1, and H3 obtaining the highest probabilities. These items fell under different metacognition strategies. As a result, Class 2 was labeled “Knowledge of Multiple Strategies” group.

The students under Class 3 tended to have knowledge of “Strategy,” since this metacognitive strategy obtained the highest conditional probability for all categories. The items E3, F3, G3, and H3 obtained the highest probabilities. These items are all under the “Strategy” group. Hence, Class 3 students were labeled “Knowledge of Strategy” group.

Class 4 students had an inclination to have knowledge of “Person,” since this class obtained the highest conditional probabilities for all the categories and options. The items E1, F1, G1, and H1 obtained the highest probabilities. These items are all under the “Person” group. Thus, Class 4 was labeled “Knowledge of Person” group.

Table 6. Conditional and Class Probabilities on the Metacognition Scale for the 5-Class Model

Item Code	Statement	Strategy	Class 1	Class 2	Class 3	Class 4	Class 5
E1	I am aware of my intellectual strengths.	Person	.00	.00	.00	1.00	.00
E2	I set specific goals before I begin a task.	Task	.99	.00	.00	.00	.00
E3	I use different learning strategies depending on the situation.	Strategy	.00	1.00	1.00	.00	1.00
F1	I know what kind of information is most important to learn.	Person	.38	.00	.00	.37	.95
F2	I have a specific purpose for each strategy I use in doing a task.	Task	.24	1.00	.00	.30	.00
F3	I summarize what I've learned after doing a learning task.	Strategy	.37	.00	1.00	.33	.00
G1	I learn best when I know something about the topic.	Person	.63	.70	.16	.65	.70
G2	I am good at organizing information.	Task	.19	.15	.16	.13	.14
G3	I have control over how well I learn.	Strategy	.17	.13	.66	.21	.16
H1	I know how well I did once I finish a test.	Person	.27	.27	.28	.36	.28
H2	I ask myself periodically if I am meeting my goals.	Task	.40	.30	.29	.32	.32
H3	I organize my time to best accomplish my goals.	Strategy	.33	.43	.43	.32	.40
	Mean Class Probability		**.23**	**.20**	**.20**	**.24**	**.13**

The last class in the model, Class 5, tended to have knowledge of both "Person and Strategy," since these metacognitive strategies obtained the highest conditional probabilities. The items E3, F1, G1, and H3 obtained the highest probabilities. These items are under the "Person" and "Strategy" groups. The students under this class tended to have a knowledge of strategy in studying for a mathematics exam and solving mathematical problems. As a result, Class 5 was labeled as "Knowledge of Person and Strategy" group.

Table 7 shows the descriptive statistics about the mathematics performance of the students using the five classes of metacognition. It can be noticed that there are slight differences in performance between the groups. Further testing (ANOVA) was conducted to investigate if the differences were significant; no differences were found (p = .61). Thus, it can be concluded that the metacognition approaches of students had no effect on the performance of the selected students in mathematics.

Table 7. Descriptive Statistics of Mathematics Performance for Five-Class Model of Metacognition

Class	Type	*N*	Mean	Std. Deviation
1	Person and Task	296	86.60	5.11
2	Multiple Strategies	267	86.75	5.03
3	Strategy	256	86.93	4.58
4	Person	320	86.86	4.93
5	Person and Strategy	174	87.35	5.18
	Total	1313	86.86	4.96

Interaction Effect of Learning Strategies and Metacognition

As shown in Table 8 below, the significance value for the interaction effect of learning strategies and metacognition on the performance of selected students in mathematics was .36, which is greater than .05. This means the null hypothesis must be rejected. Thus, learning strategies and metacognition of students did not affect the performance of students in mathematics in this study. The purpose of using Two-way Analysis of Variance was to test the interaction effect of two factors on the dependent variable. In this case, the interaction effect was not significant, implying that the learning strategies and metacognition of students had no interaction effects on their performance in mathematics. However, the learning strategy value (*p* = .037) was significant, while the effect of metacognition was not significant. This implies that the learning strategies alone can affect the mathematics performance of the selected students. As shown in the partial eta squared column, the effect of interaction on the performance of students was only 1.3%, which is quite insignificant. In addition, learning strategies accounted for 0.8% effect, while metacognition recorded a 0.2% effect on the variation of the mathematics performance of the selected students.

Table 8. Interaction Effect of Learning Strategies and Metacognition on Student Performance

Sources	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	**Sig.**	**Partial Eta Squared**
Corrected Model	737.32	24	30.72	1.26	.184	.023
Intercept	8,465,277.03	1	8,465,277.03	345,843.08	.000	.996
Metacognition	65.23	4	16.31	.67	.615	.002
Learning Strategies	250.09	4	62.52	2.55	.037	.008
Interaction	426.33	16	26.65	1.09	.361	.013
Error	31,526.66	1288	24.48			
Total	9,937,762.75	1313				
Corrected Total	**32,263.97**	**1312**				

In terms of learning strategies, the results of this study confirmed the results of other studies conducted in the Philippines and abroad. However, in terms of metacognition, the results of this study contradict the results of all other studies conducted locally and internationally. This might be because the sample for this study was senior high school students. Senior high school in the Philippines just started in 2016. The students might still be in the period of adjusting from being in high school to preparing for college. Another reason to be considered is that the results of studies conducted in other countries might differ on account of differences in their curricula. Hence, this study showed that the learning strategies practiced by students affect their performance in mathematics. On the other hand, this study does not support the theory that metacognition practiced by students affected their performance.

Conclusions

Learning strategies and metacognition of the students are vital in achieving higher performance in mathematics. In this study, it was found that the learning strategies affected the way students study and prepare for examinations in mathematics. However, metacognition was not shown to affect their performance. Hence, educators should focus more on developing students' learning strategies. The Department of Education could draft policies for using the empirically sound results of this study to boost the mathematical abilities of learners.

Limitations

A similar study could be conducted using other types of learning strategies and metacognition. It is recommended to have a larger sample size to ensure the aptness of the Latent Class Models. A more in-depth LCA could be done regarding the metacognition strategies of the students using other metacognition types.

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